2002 Human-Technology Integration Colloquium Series
Air Force Research Laboratory
Human Effectiveness Directorate

Living With Agents: From Human-Agent Teamwork to Cognitive Prostheses

Jeff Bradshaw, Ph.D.
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Living With Agents: From Human-Agent Teamwork to Cognitive Prostheses

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institute for
Human & Machine Cognition

University of West

institute for

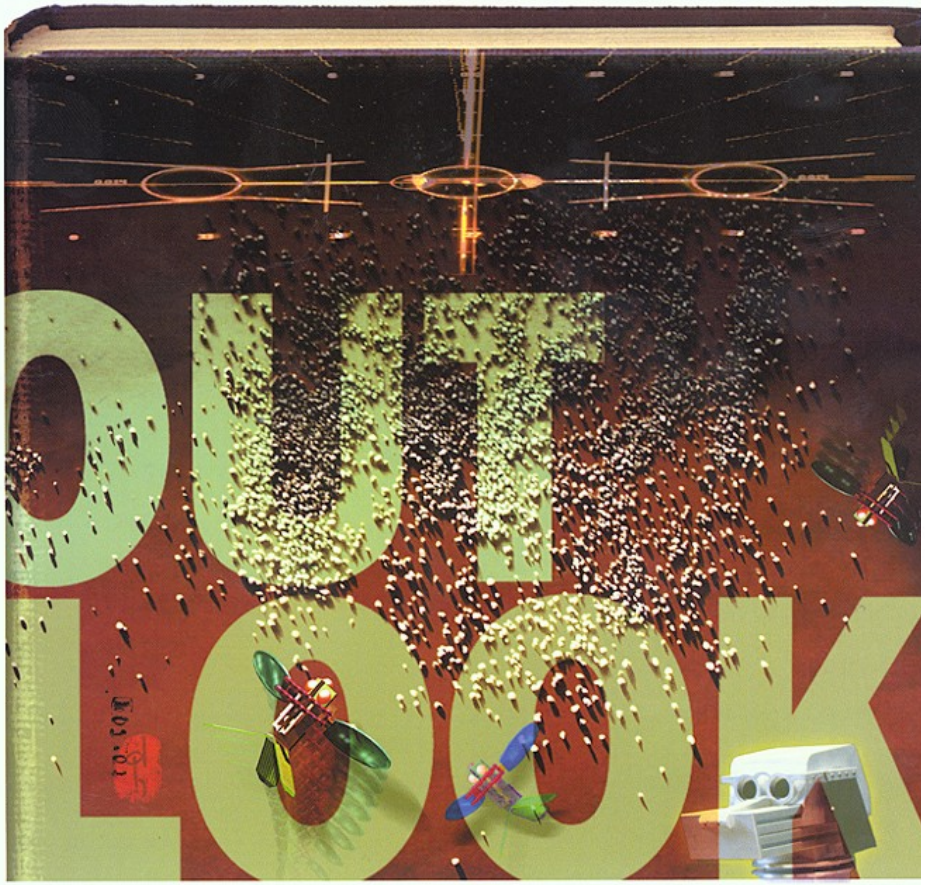
Human & Machine Cognition

Director: Ken Ford
Associate Directors:
Alberto Cañas, Tim Wright, Jack Hansen

Selected Researchers:
Next-Generation Interfaces (David Still, Anil Raj)
Work Systems Design (Bill Clancey)
Intelligent Data Mining (Clark Glymour, Rattikorn He
Knowledge Modeling (Robert Hoffman, Paul Feltovich
Computer-Mediated Learning (Alberto Cañas, Joe No
Knowledge Representation (Pat Hayes)
Agents (Jeff Bradshaw, Niranjan Suri)
Human-Machine Interaction (James Allen)
Robotic Prostheses (Jerrey Pratt)

New 40 So. Alcaniz Buildings

COMPUTER
Innovative Technology for Computer Professionals
January 2001



Cyberprivacy in the New Millennium

The KWIC and the Dead

Peer-to-Pee Networking

IEEE COMPUTER SOCIETY
IEEE
http://computer.org

A Look Ahead at Society Activities in 2001, p. 88

Thinking Outside the Box at the IHMC

Scott Hamilton
Computer

The IHMC's human-centered-computing approach to research embraces a closely interrelated collection of theory-based, yet highly practical, applications.

A decade ago, research into artificial intelligence came under fire from many sectors. Savaged by critics for being overhyped and failing to deliver on its promises, AI's name became so tarnished that many of its proponents began referring to it by other terms. Debates within the community itself further impeded progress and left many researchers feeling as if the discipline had lost its way.

Several projects now under way at facilities in Pensacola, Florida, may provide the spark to ignite an AI renaissance, one that can leverage renewed interest in applying the technology to next-generation interfaces, knowledge modeling and sharing, intelligent agents, data mining and—perhaps most significantly—extending human cognition.

Founded by Kenneth M. Ford and Alberto Cañas at the University of West Florida in 1990, the Institute for Human and Machine Cognition houses experts in computer science and engineering, medicine and cognitive psychology, statistics and mathematics, and the social sciences and philosophy. The IHMC has drawn scientists and researchers from these diverse backgrounds to study the complex phenomenon of human cognition and, ultimately, to develop cognitive prostheses that will augment our capabilities and overcome our limitations.

HUMAN-CENTERED COMPUTING

The IHMC itself came about when its founders realized that the exciting work in computer science would happen in the boundary spaces between disciplines. Further, this trend dictated that the traditional, and in some ways accidental, need for academic specialization would become increasingly counterproductive. The IHMC will base its research on the idea of leveraging and extending humans through computers and computer programs. If we abandon the Turing Test as AI's measure of success, Ford notes, the goal naturally shifts from making artificial superhumans who can replace us to making superhumanly intelligent artifacts that can amplify and support our own cognitive abilities.[1]

Cognitive prostheses

To understand cognitive prostheses, consider eyeglasses, a well-known ocular prosthesis. Eyeglasses leverage and extend our ability to see, but in no way model our eyes: They don't look or act like them and wouldn't pass a Turing test for being an eye. We can also look upon the steam shovel as a muscular prosthesis that supplements even the strongest person's inherent physical limitations.

The IHMC wants to create the cognitive equivalent of eyeglasses—and to a lesser extent perception, since perception is part and parcel of cognition. From this perspective, the minimum unit of discussion includes dryware, wetware, and the environment in which humans work.

Researchers at IHMC explore what's known about how humans function—specifically, how the eye or brain function—and start from first principles to build a total system that fits and includes the user. The prostheses metaphor implies the importance of designing systems that fit the human and machine components together in ways that synergistically exploit their respective strengths.

The IHMC's approach turns much traditional design philosophy on its head. For example, the dials

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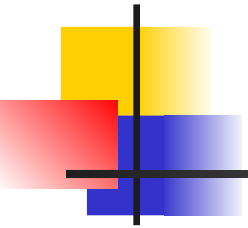
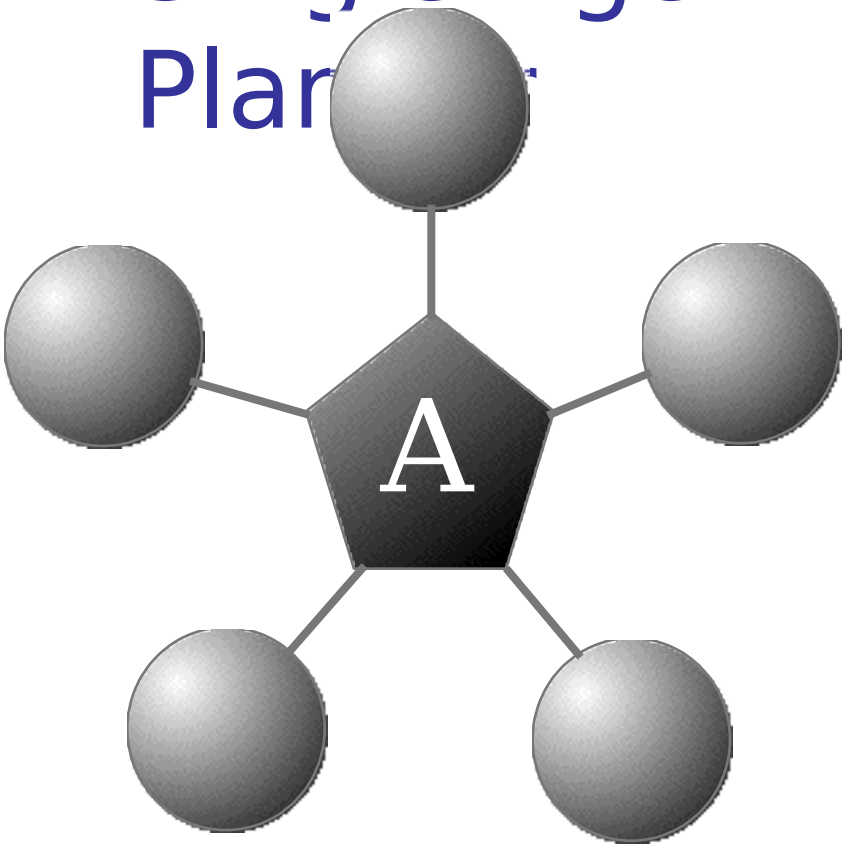


Brief History of Agents

- 1000-1940: Not much happened
- 1940’s: Servomechanisms, factory control, aircraft flight controls
- Early 1950’s: Shift from hardware to software
- Late 1950’s: McCarthy & Selfridge’s “advice takers”
- 1970’s: Artificial Intelligence (AI)
- 1980’s: Distributed Artificial Intelligence (DAI), Intelligent User Interfaces
- 1990’s: Broader range of agent types
  - Collaborative agents
  - Interface agents
  - Bots
  - Lifelike agents
  - Mobile agents

Evolution of System Connectivity

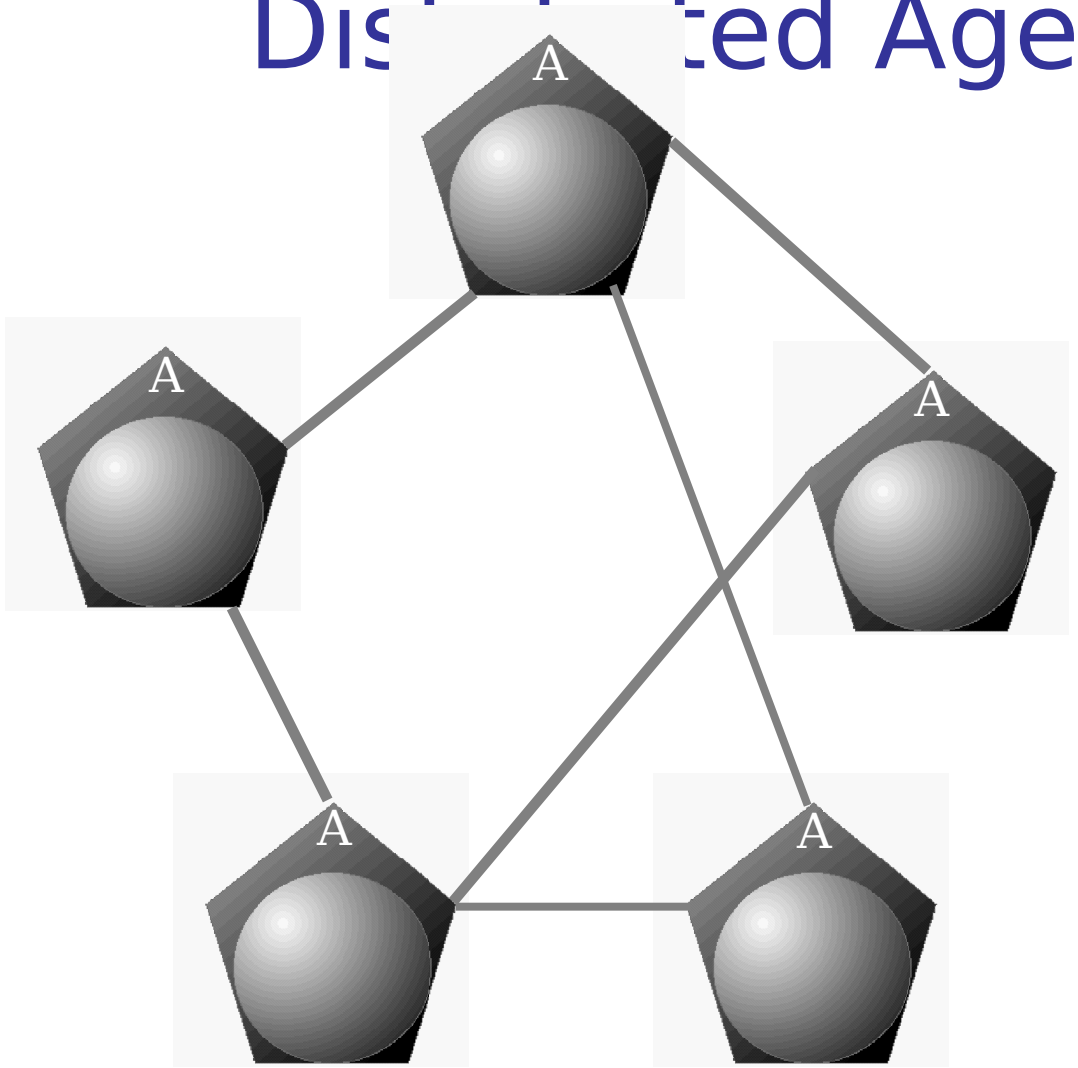
Cooperating Systems with Single Agent as Global Plan



- Benefit: Agent coordinates component interaction
- Issue: Single coordinating agent becomes a bottleneck for an otherwise distributed system

(adapted from Brodie, 1

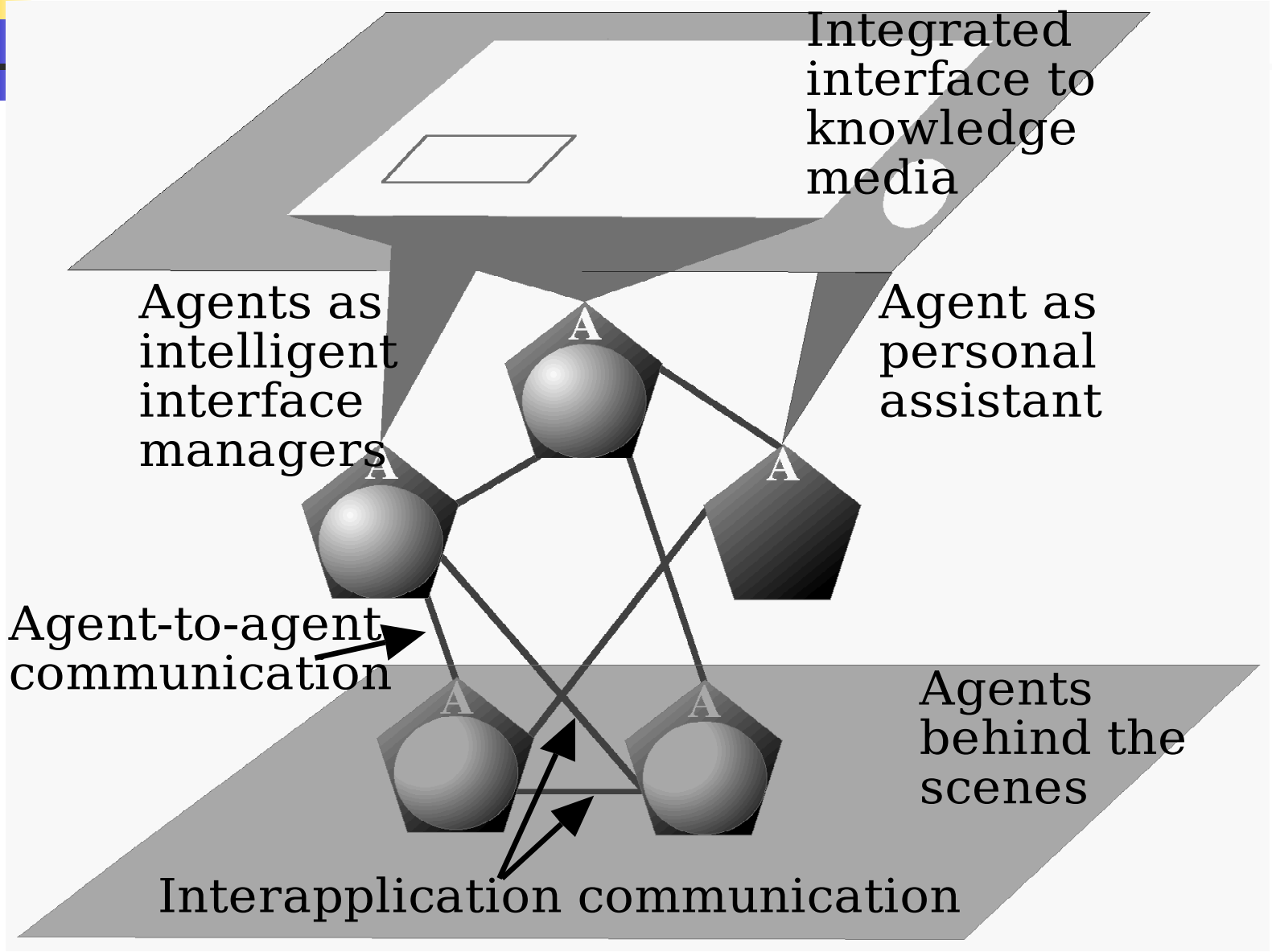
Cooperating System with Distributed Agents



- Selective wrapping of system components (i.e., not every component or service need be an agent)
- Distributed agents provide scalable solution

(adapted from Brodie, 19

Agent-Enabled System



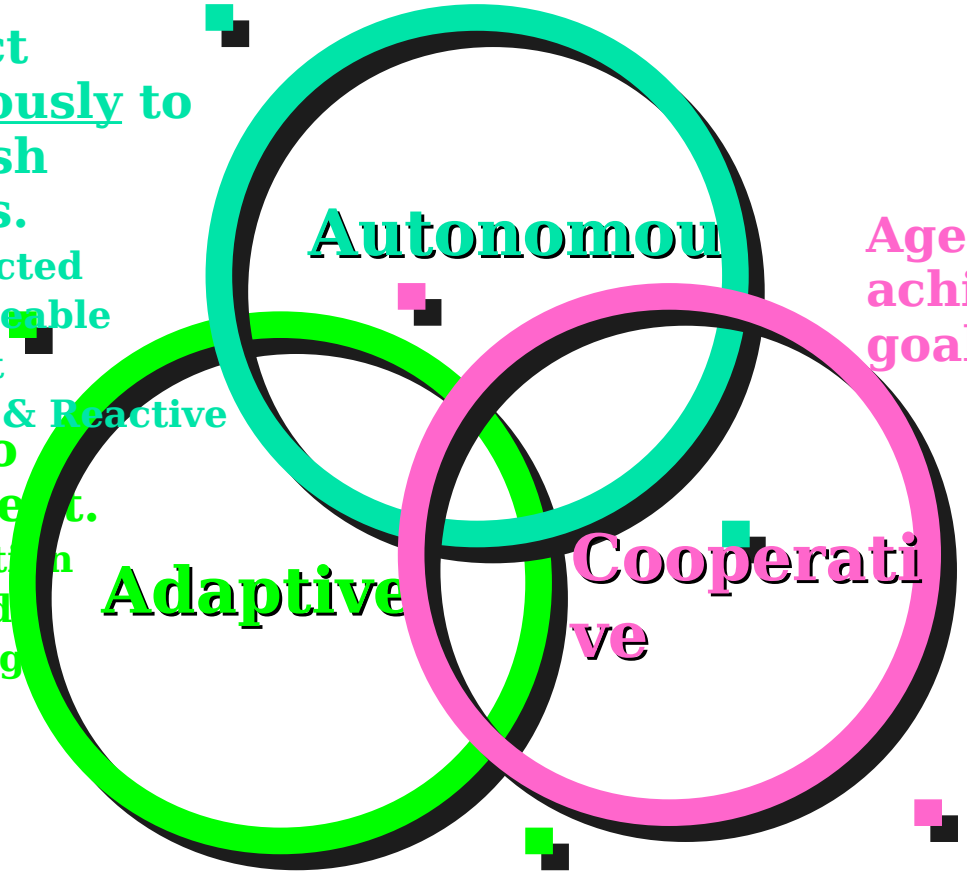
Key Agent Characteristics

Agents act autonomously to accomplish objectives.

- Goal-Directed
- Knowledgeable
- Persistent
- Proactive & Reactive

Agents adapt to their environment.

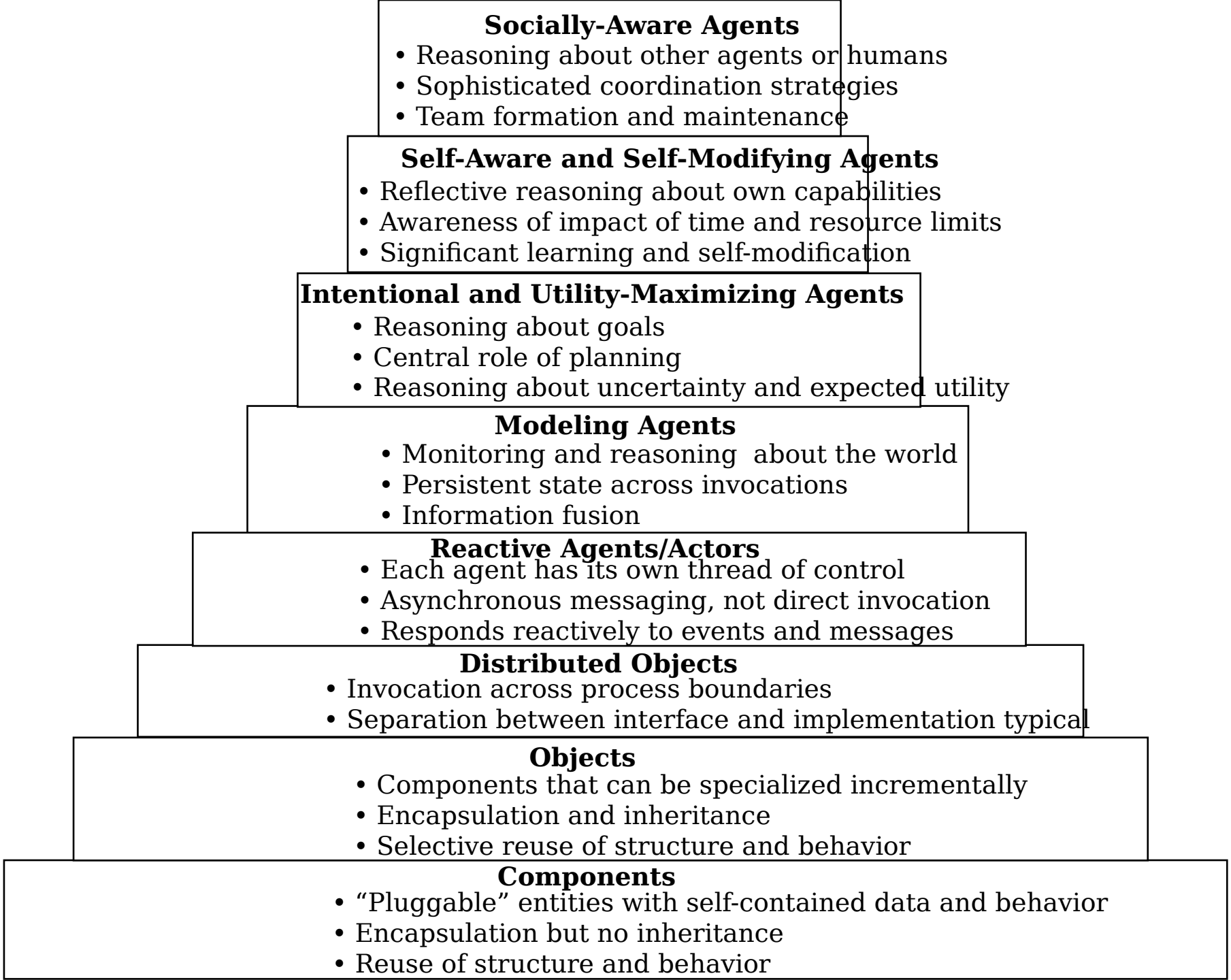
- Dynamic Interaction
- Alternate Method
- Machine Learning



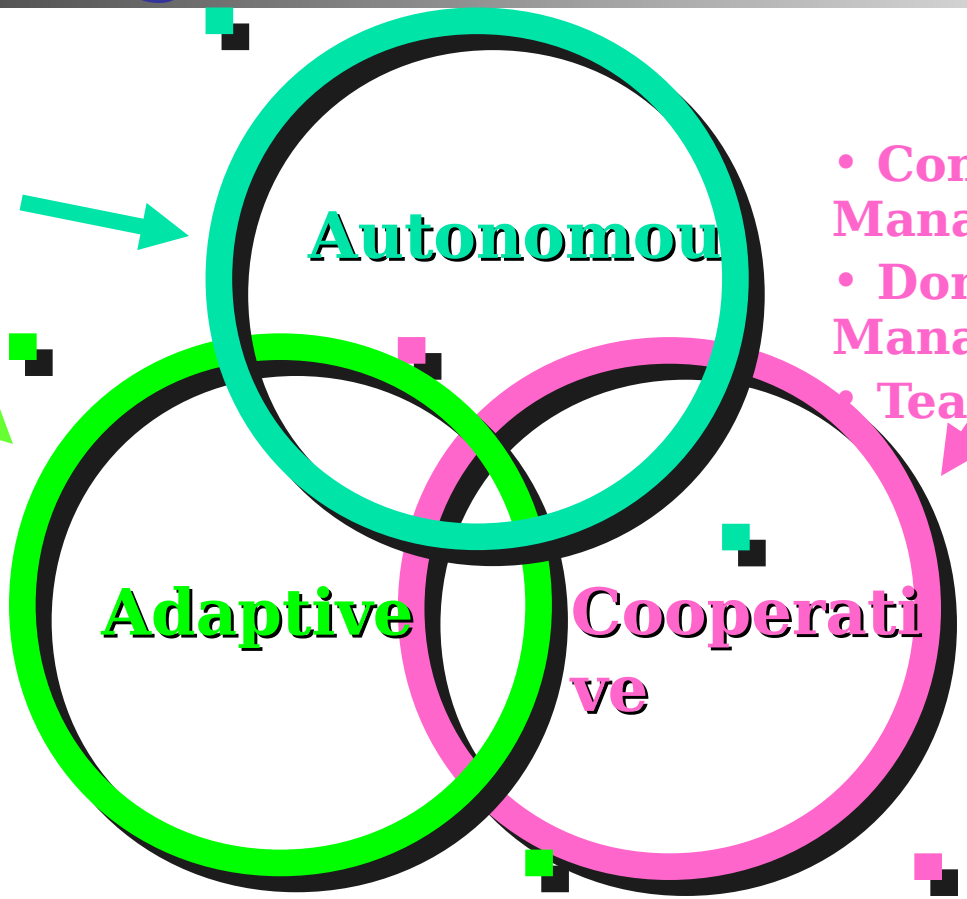
Agents cooperate to achieve common goals.

- Communication Protocols
- Knowledge-Sharing
- Coordination Strategies
- Negotiation Protocols

Mobile:
Agents can either be static or mobile, depending on bandwidth requirements, data vs. program size, communication latency, and network stability


Socially-Aware Agents
• Reasoning about other agents or humans
• Sophisticated coordination strategies
• Team formation and maintenance
Self-Aware and Self-Modifying Agents
• Reflective reasoning about own capabilities
• Awareness of impact of time and resource limits
• Significant learning and self-modification
Intentional and Utility-Maximizing Agents
• Reasoning about goals
• Central role of planning
• Reasoning about uncertainty and expected utility
Modeling Agents
• Monitoring and reasoning about the world
• Persistent state across invocations
• Information fusion
Reactive Agents/Actors
• Each agent has its own thread of control
• Asynchronous messaging, not direct invocation
• Responds reactively to events and messages
Distributed Objects
• Invocation across process boundaries
• Separation between interface and implementation typical
Objects
• Components that can be specialized incrementally
• Encapsulation and inheritance
• Selective reuse of structure and behavior
Components
• “Pluggable” entities with self-contained data and behavior
• Encapsulation but no inheritance
• Reuse of structure and behavior

IHMC Agent Research Topics



- Adjustable Autonomy

- Conversation Management
- Domain Management
- Teamwork

- Strong Mobility
- Safe Execution

Mobile:
Agents can either be static or mobile, depending on bandwidth requirements, data vs. program size, communication latency, and network stability

IHMC Agent Projects

- **Funded Proposals**
- DARPA CoABS: Agent Domain Management and Coalition Operations/NOMADS (1998-2002)
- DARPA Ultra*Log: Survivable Agent Execution Environment (2001-2004)
- DARPA Augmented Cognition (2001-)
- NASA Intelligent Systems: Mixed Human-Robotic Teamwork (2001-2004)
  - NASA HCC Workshop, IHMC, Feb. 26-28, 2002
- NASA Cross-Enterprise Program: Design of Systems for Human-Robotic Teams (2001-2004)
- ITAC: Software Agents for the Warfighter (2001)
- Army Alliance: Agents in Dynamic Environments and Mobile Field Settings (2001-2007)
- NavSea Panama City: Agent Control of Unmanned Vehicles (2001-)
- Navy Expeditionary Sensor Grid/FBE-J (2001-)
- Navy Coalition Experiment/FBE-J (2001-)

Outstanding Proposals

- DARPA NICCI - Habitats (potential new start)

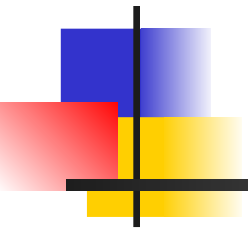
IHMC Agent Research Collaborations

Agent Collaborative Efforts

- FIPA Abstract Architecture
- Java Agent Services (JSR 87, now in public review)
- Java Resource Management (pending)
- OMG Agents and Mobility WG's
- Coalition Operations Experiment (CoAX)
- Mobility Technology Integration Experiment (MobTIE)

Agent Research Partners

- Boeing
- Nokia
- Fujitsu
- Sun Labs
- NIST (pending)



Design for Collaboration for Human-Robotic Teams in Practice

Alessandro Acquisti (RIACS/UCB)
Jeffrey M. Bradshaw (UWF/IHMC)
William J. Clancey (UWF/IHMC and NASA Ames)
Renia Jeffers (UWF/IHMC)
Debbie Prescott (The Boeing Company)
Maarten Sierhuis (RIACS)
Niranjan Suri (UWF/IHMC)
Andrzej Uszok (UWF/IHMC)
Ron Van Hoof (QSS)

Acknowledgements

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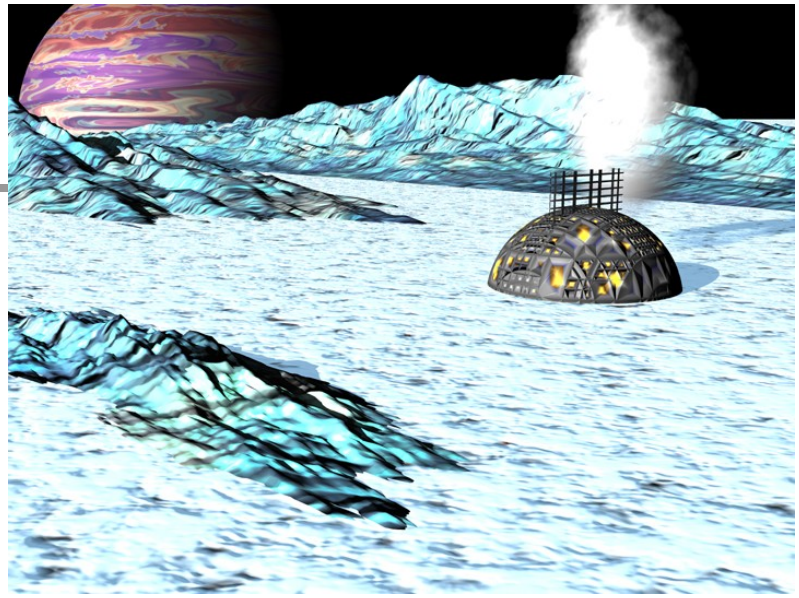
- Beth Ann Hockey, Natural Language Interface
- Nicola Muscettola, Autonomy Control
- Pat Hayes, UWF/IHMC
- Mike Shafto
- Adam Sweet, Simulation and Modeling Research

Outline

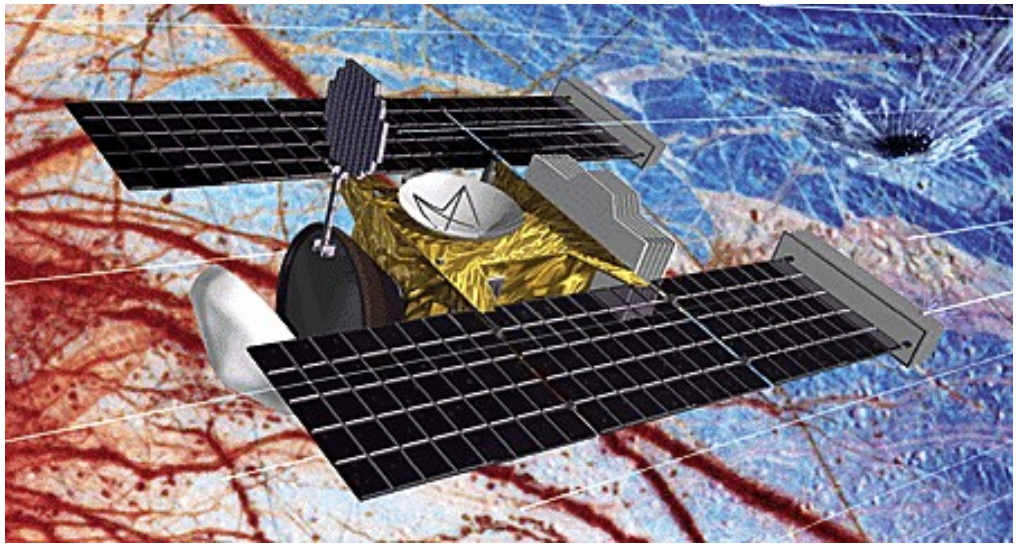
- ***Project Overview***
- Human-Robotic Teamwork
- Work Practice Study
- Status and Next Steps

Autonomous Space Systems



Autonomous Europa Submar

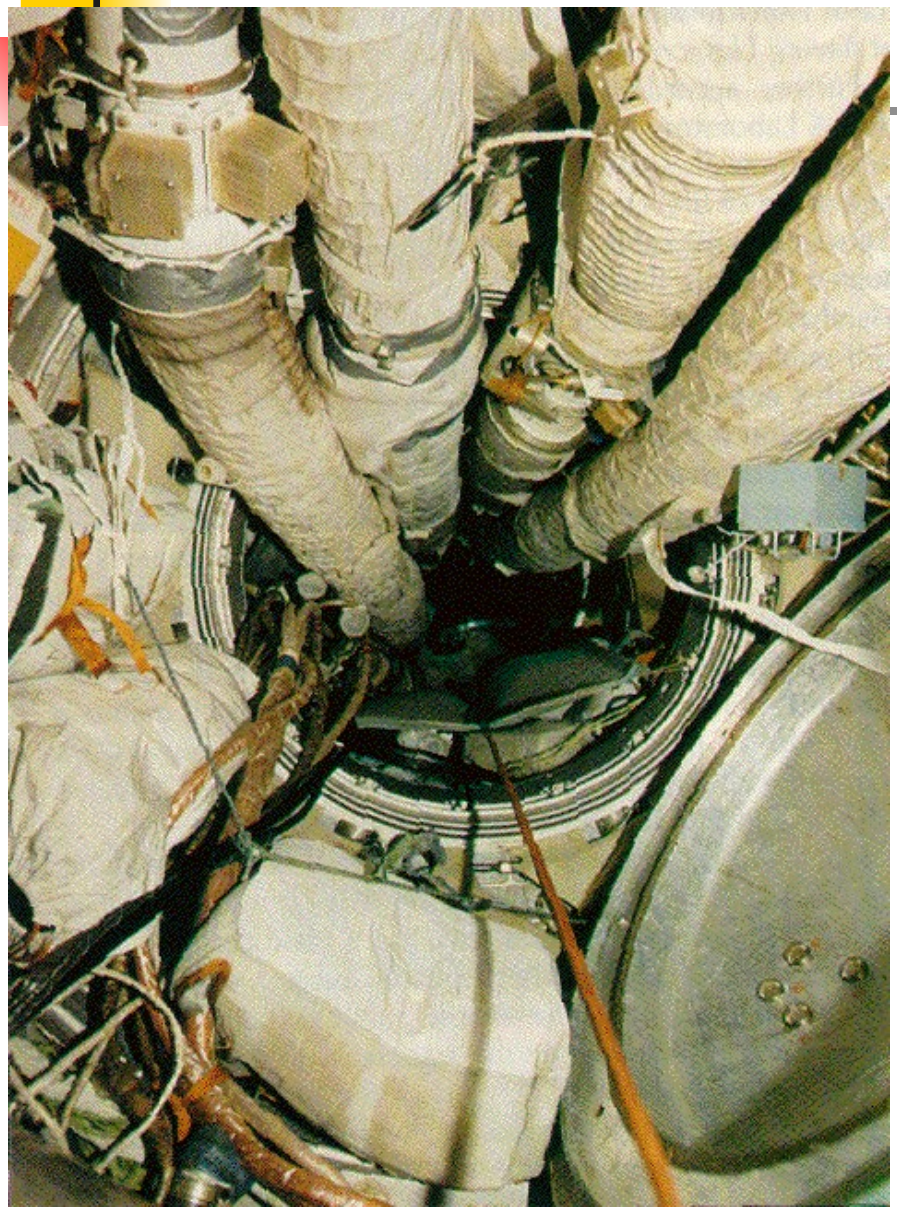
QuickTime™ and a
Photo - JPEG decompressor
are needed to see this picture



Deep Space Missions

Europa “Ice Clipper”

Dangers of Inner Space



- Jungle of cables, power lines,
  air ducts, and drag lines
  obstructing the hatchway

- Protruding debris

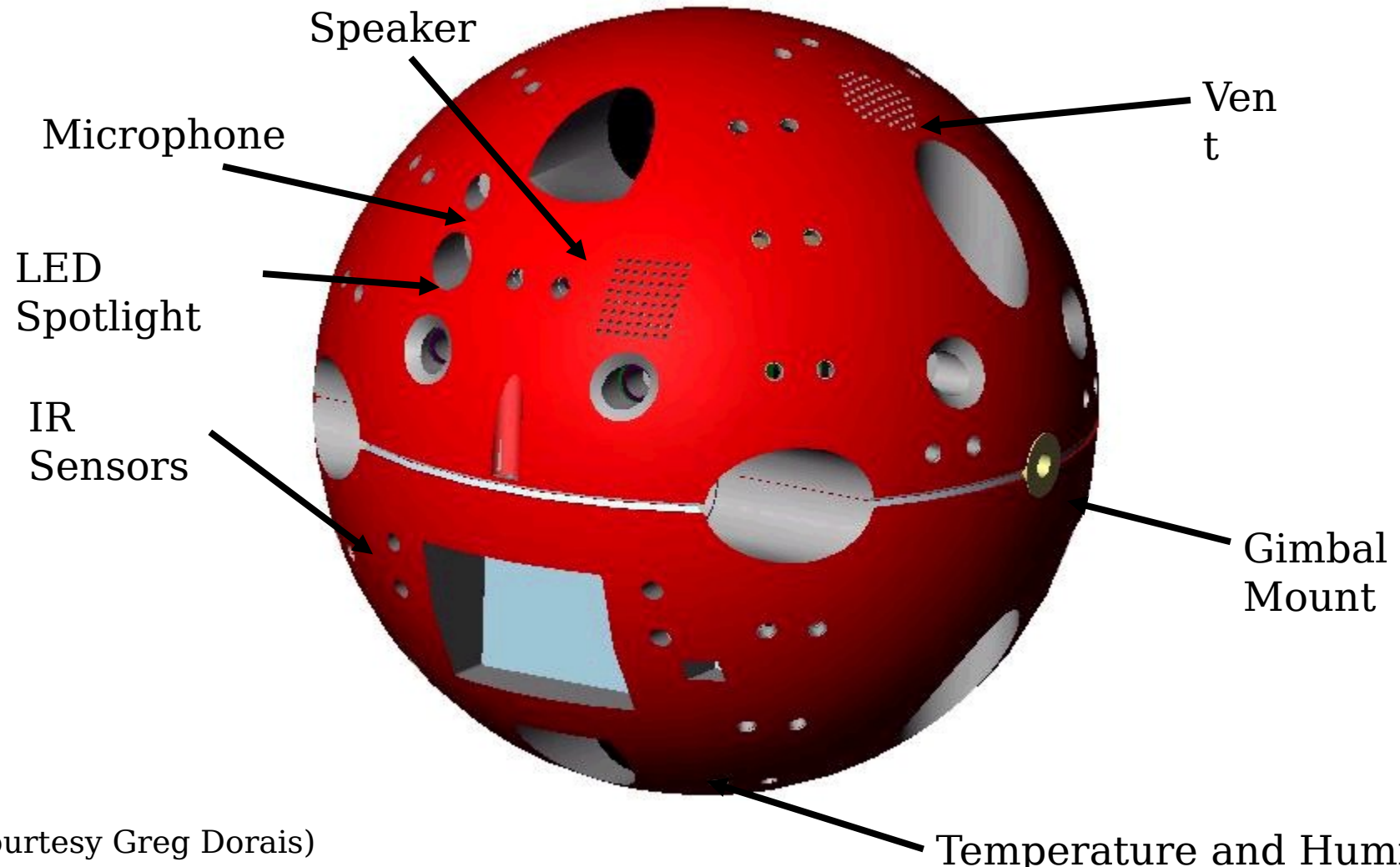
- Other environmental hazards

Complex Demands on Crew Members

Shuttle Mission 89 Flight:

"One astronaut, Andy Thomas, will undertake several hundred research runs involving 26 different science projects in five disciplines. The projects are provided by 33 principal investigators from the U.S., Canada, Germany and the U.K."

Personal Satellite Assistant



(Courtesy Greg Dorais)

Core Capabilities for PSA

- Navigation and control
  - Safety considerations with humans and micro-gravity experiments
  - Issues in controlling velocity and in maintaining stationary position
- Sensing
  - Active super-sensor in humanly inaccessible sites
  - Validation of reports from fixed sensor suite
- Wireless communication
  - Spacecraft LAN and ground networks
  - Code mobility supporting efficient opportunistic distribution of computing tasks between PSA and off-PSA processors
- Diagnostics
  - Selective automated fault isolation and recovery
  - Intelligent performance support for humans

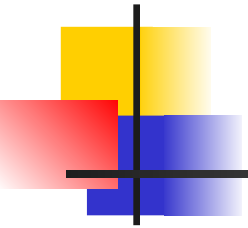
PSA and Human-Robotic Teamwork Research

- The Personal Satellite Assistant (PSA) is an attractive testbed for human-robotic teamwork research
  - PSA-focused research can be applied in other areas
  - Examples: JSC Robonaut and Mini AERCam teams

- Keywords “personal” and “assistant” capture interesting differences from other autonomous spacecraft. Challenges for:
  - Human interface
  - Adjustable autonomy
  - Teamwork

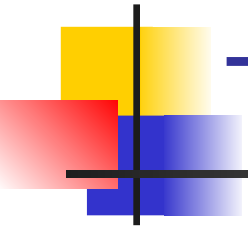
Human Interface

- *Objective: “Hands off” (not merely “hands free”) operation*
  - Initial speech understanding interface using restricted command language (RIALIST group)
  - Eventual integration of speech with gestures and references to complex objects and locations
  - PSA speech and other sound generation capabilities may be useful



Adjustable Autonomy

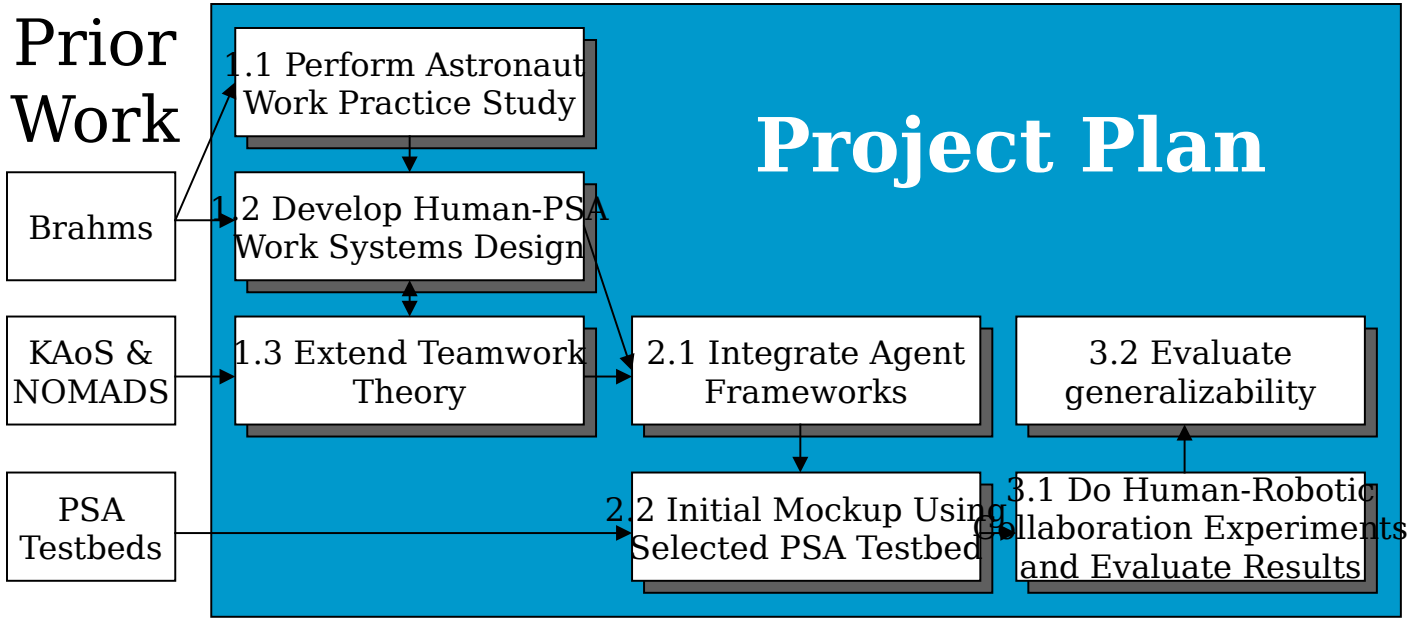
- *Objective: Constantly adjust degree of autonomy to match thresholds of human comfort vs. convenience*
  - Discard assumptions about fixed “optimal” level of autonomy
    - May vary by task or over time
    - Unforeseen events may require adjustment
  - Kinds of dimensions to be adjusted:
    - Type or complexity of executable commands
    - Which subsystems may be controlled
    - When manual control may be overridden
    - Duration of autonomous operation



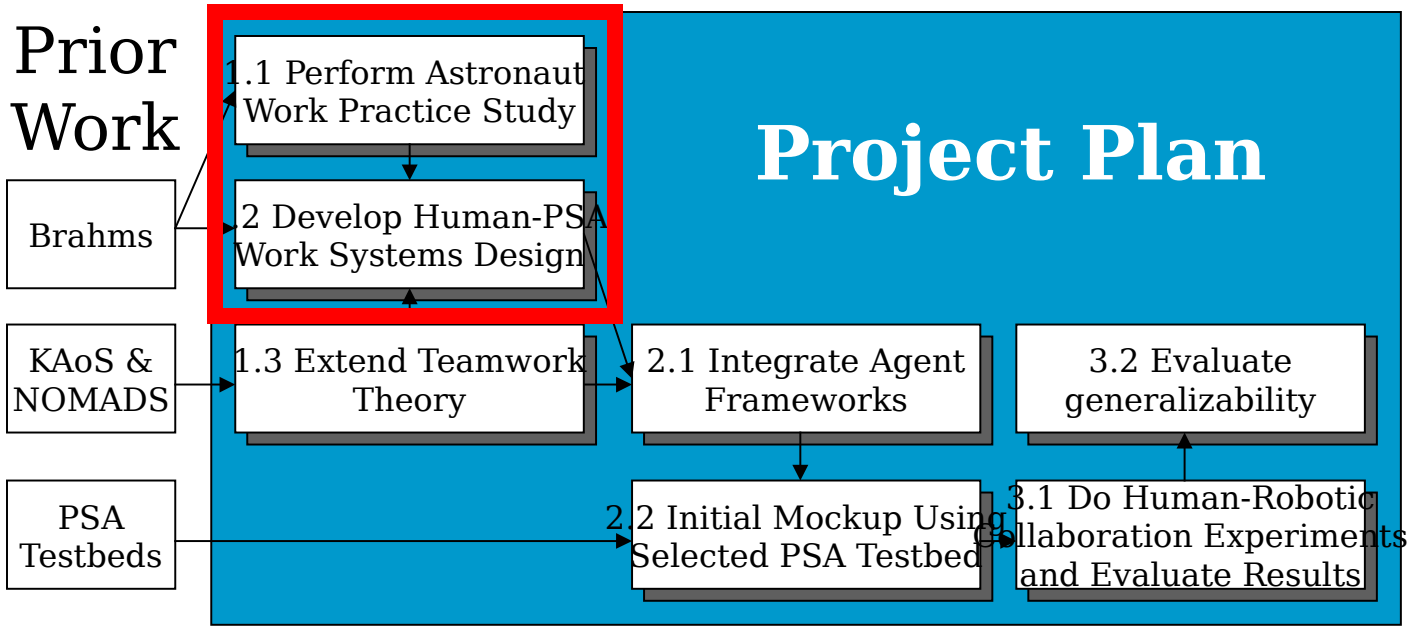
Teamwork Model

- *Objective: Enable mixed groups of artificial agents and humans to work together safely and effectively*
  - Attempt to develop a model of teamwork knowledge that can be reused across many domains and settings
  - Reduce need for special-purpose recovery and exception-handling procedures
  - Incorporate best of previous research on collaboration and teamwork
  - Ground in new results from work practice study experience

Project Overview


Prior Work
Brahms
KAoS & NOMADS
PSA Testbeds
Project Plan
1.1 Perform Astronaut Work Practice Study
1.2 Develop Human-PSA Work Systems Design
1.3 Extend Teamwork Theory
2.1 Integrate Agent Frameworks
2.2 Initial Mockup Using Selected PSA Testbed
3.1 Do Human-Robotic Collaboration Experiments and Evaluate Results
3.2 Evaluate generalizability

Project Overview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Work Practice Study and Work Systems Design

- Broader view of the work organization, geography, multi-agent communication and collaboration than typical human factors studies
- Sources
  - Interviews with astronauts
  - ISS documentation and procedures
  - ISS and Shuttle astronaut videos
- Using the Brahms multi-agent modeling and simulation environment
- Design model will become basis for agent execution model

Brahms modeling language

GROUPS are composed of

AGENTS having

BELIEFS and doing

ACTIVITIES defined by

WORKFRAMES that contain

PRECONDITIONS, matching agent's beliefs,

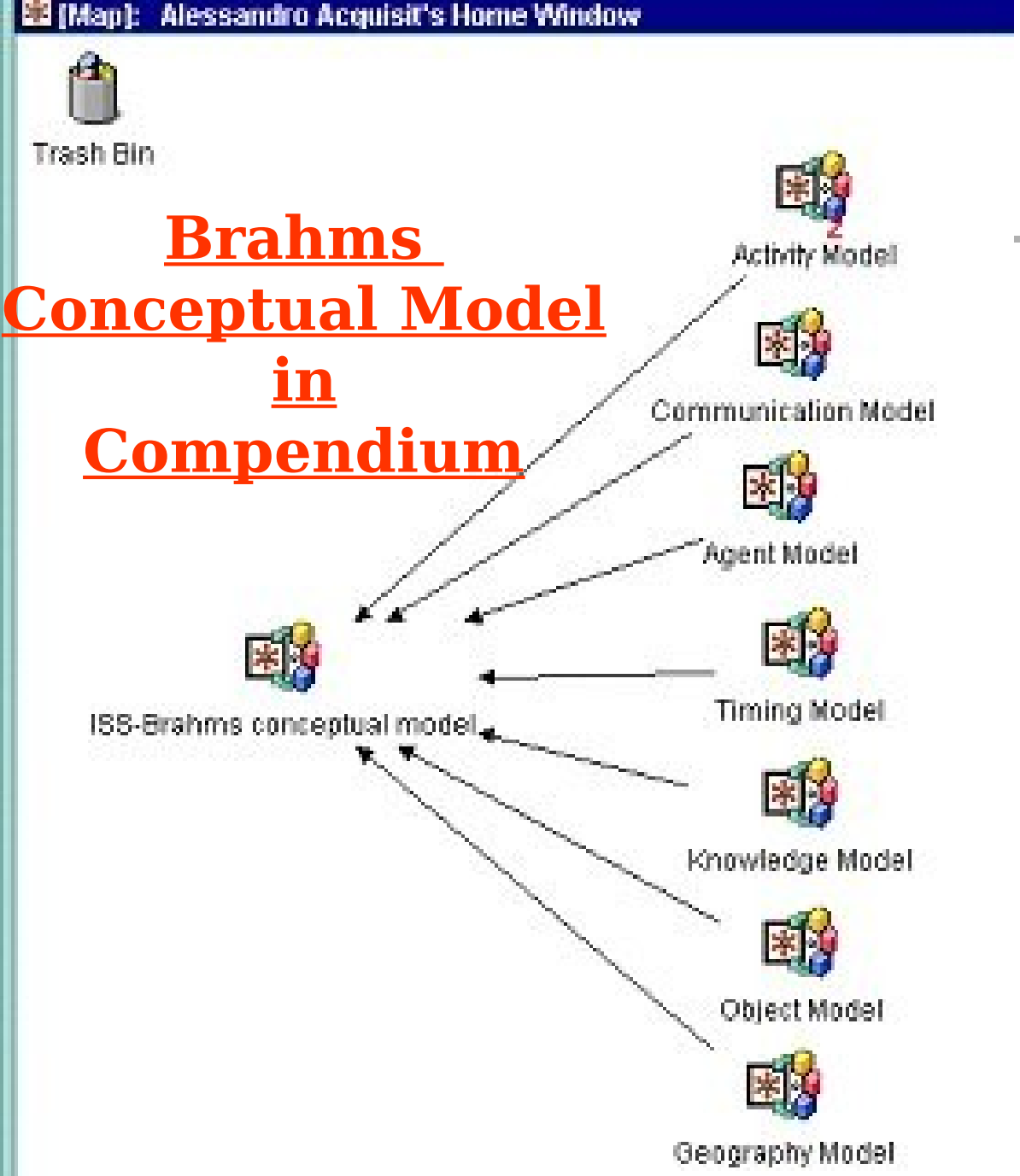
performing (decomposed) ACTIVITIES,

detecting facts in the world through DETECTABLES,

allowing INTERUPTIONS, IMPASSES

concluding new agent BELIEFS and changing the world's FACTS through CONSEQUENCES

Brahms Conceptual Model in Compendium



- Agent Model
- Activity Model
- Timing Model
- Communication Mod
- Object Model
- Geography Model
- Knowledge Model

Astronaut Work Practice Study

Objective:

- Develop a multiagent simulation model of a day in the life of the ISS crew

Focus on:

- Crew activities (who is doing what)
- How do they know what to do and how?
- Where are things located
- Collaboration and coordination between crew, ground and systems.

ISS Expedition 1-2
Video Analysis

“A Day in the Life Onboard the ISS”

- Recurring activities
  - e.g. Sleep, Breakfast, Bio-needs
- Day-specific activities
  - e.g. Daily planning conference with MSC
- Planned activities (OSTP)
  - e.g. Replacement of urine-receptacle in toilet
- Unscheduled activities
  - e.g. Emergencies, Personal activities

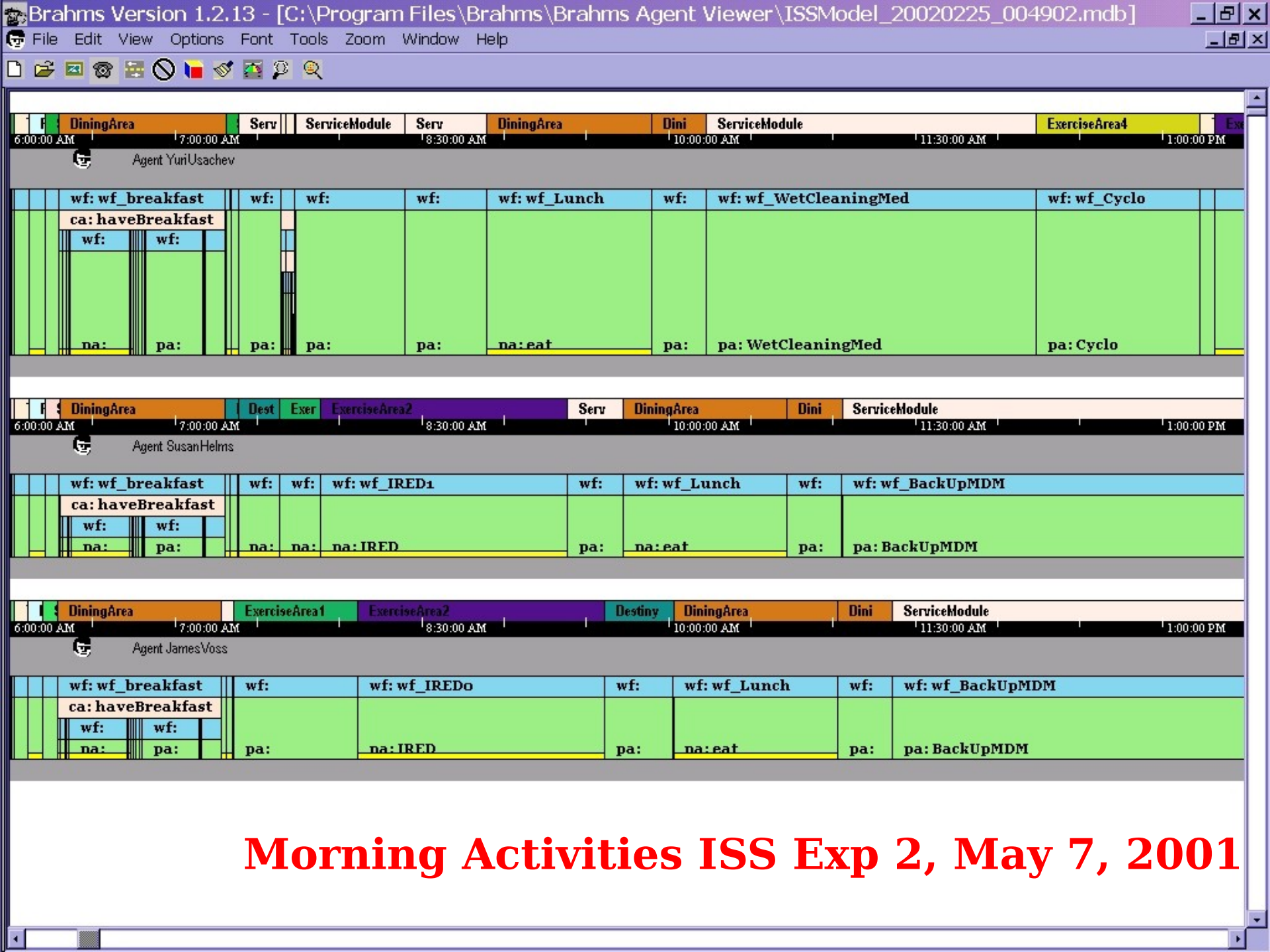
Discrepancies Between Plan and Practice

Examples

Cause of Discrepancy	Plan	Practice
Procedures not easily accessible or not clear	**During emergency, refer to procedure**	**During emergency, rely on training and memory**
Noise level on internal audio system	**Use internal audio system to communicate between modules**	**Move from module to module to communicate with crew members**
Personal preferences	**Do medical tests as scheduled**	**Do medical test in the morning**
Shared resources not always available	**Upload on laptop computer medical/physical data after experiment/exercise**	**Upload data rarely**
Personal habits	**Read procedure**	**Read electronic procedure (from laptop), or read printed procedure**
Inventory system not always reliable	**Use tools indicated in procedure**	**Tools must be found and time can be lost in this operation**

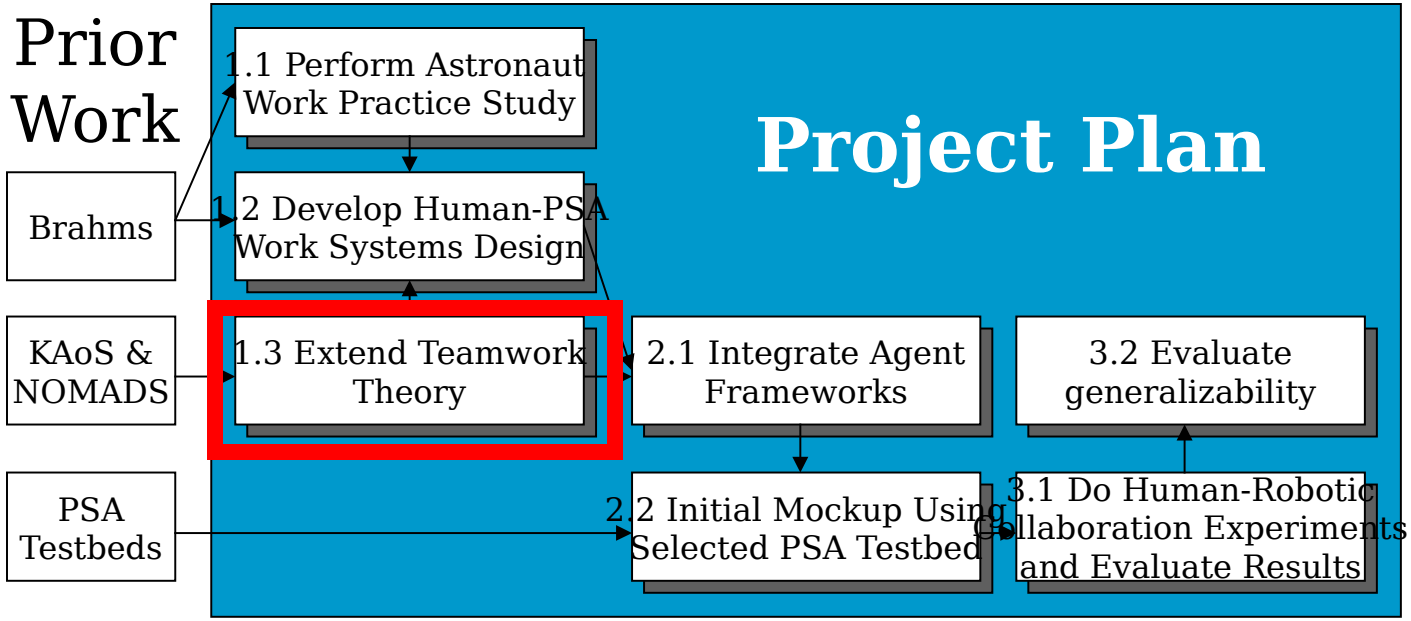
Modeling Status

- Expedition 2, May 7, 2001
- Planned activities are represented in OSTP objects
  - OSTP objects are created by Planning Officer Agent
  - OSTP objects are uploaded to ISS Alpha
- Crew agents read OSTP after breakfast and create mental "plan" that is changed as the day goes on.
  - Agents use their personal computers to read daily plan
- Crew agents perform their daily activities
- Most activities not yet decomposed
  - Breakfast
  - Replacing urine-receptacle
- Modeling research issues
  - Representing ISS procedures for performing activities
  - Use these to drive how agents perform planned activities
  - Issue: How to integrate pre-specified procedures with performing them in practice?


Brahms Version 1.2.13 - [C:\Program Files\Brahms\Brahms Agent Viewer\ISSModel_20020225_004902.mdb]
File Edit View Options Font Tools Zoom Window Help
DiningArea Serv ServiceModule Serv DiningArea Dini ServiceModule ExerciseArea4
6:00:00 AM 7:00:00 AM 8:30:00 AM 10:00:00 AM 11:30:00 AM 1:00:00 PM
Agent YuriUsachev
wf: wf_breakfast wf: wf: wf: wf: wf_Lunch wf: wf: wf_WetCleaningMed wf: wf_Cyclo
ca: haveBreakfast
wf: wf:
pa: pa: pa: pa: pa: pa:eat pa: pa: WetCleaningMed pa: Cyclo
DiningArea Dest Exer ExerciseArea2 Serv DiningArea Dini ServiceModule
6:00:00 AM 7:00:00 AM 8:30:00 AM 10:00:00 AM 11:30:00 AM 1:00:00 PM
Agent SusanHelms
wf: wf_breakfast wf: wf: wf: wf_IRED1 wf: wf: wf_Lunch wf: wf: wf_BackUpMDM
ca: haveBreakfast
wf: wf:
pa: pa: pa: pa: pa:IRED pa: pa:eat pa: pa: BackUpMDM
DiningArea ExerciseArea1 ExerciseArea2 Destiny DiningArea Dini ServiceModule
6:00:00 AM 7:00:00 AM 8:30:00 AM 10:00:00 AM 11:30:00 AM 1:00:00 PM
Agent JamesVoss
wf: wf_breakfast wf: wf: wf_IREDo wf: wf: wf_Lunch wf: wf: wf_BackUpMDM
ca: haveBreakfast
wf: wf:
pa: pa: pa: pa:IRED pa: pa:eat pa: pa: BackUpMDM

Morning Activities ISS Exp 2, May 7, 2001

Project Overview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Some of the Reasons that Designing for Agent Teamwork is Hard

- Development of agent teams is *labor-intensive* due to the need for large numbers of non-reusable domain-specific coordination activities.
- Team plans are *brittle*. It is impossible to anticipate all possible team-member failures, unreliable communication, or divergent team member beliefs.
- Coordination in teamwork is *situation- and context-dependent.* Deep understanding of how coordination occurs in practice is necessary to take these dependencies into account.
- *Scaling up* to large teams is impractical. The sheer number of possible interactions and failure conditions makes the development of large-scale domain-specific coordination models impractical.
- Because general-purpose knowledge about teamwork is not explicitly modeled, *agents cannot learn about teamwork* in order to avoid failures in the future.

(Modified from Milind Tambe)

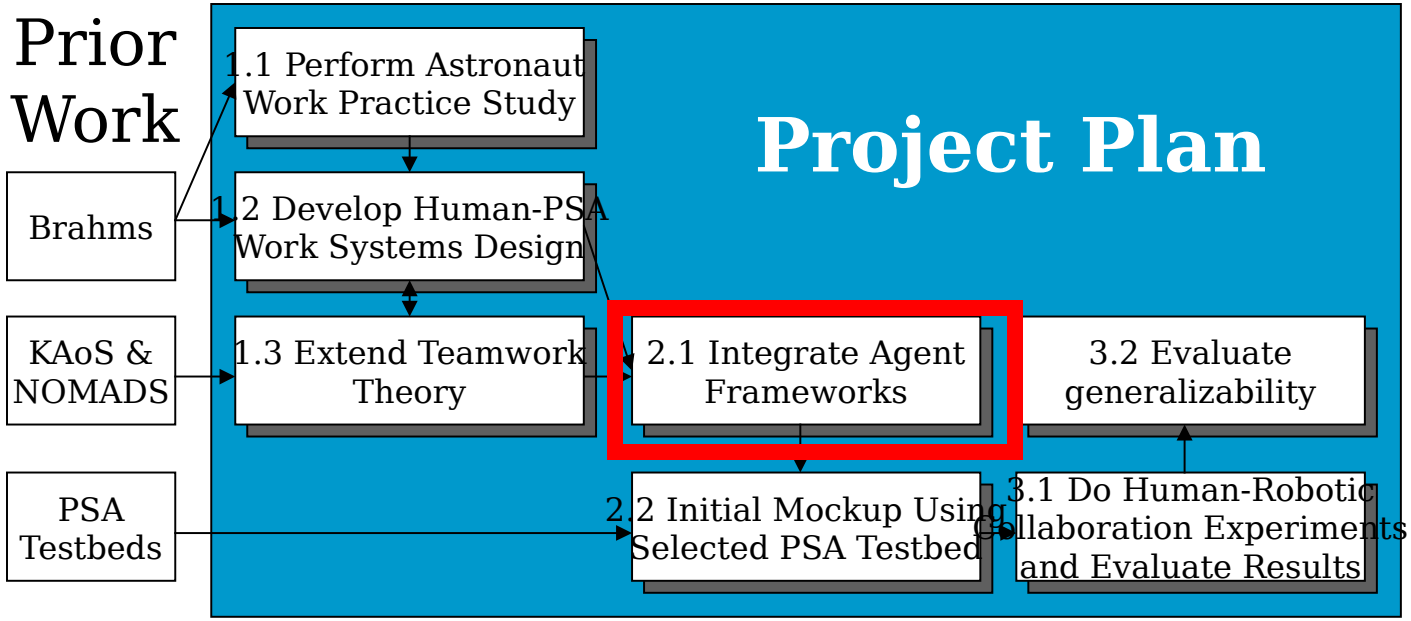
Cohen and Levesque: Theory of Teamwork

- Basic concepts:
  - Agents form teams by adopting joint persistent goals (JPG's) to achieve a team action
  - JPG's hold if and only if all team members mutually believe:
    - the goal is not yet achieved
    - they want the goal to be achieved
    - until the goal is known to be achieved, unachievable, or no longer relevant, they should persist in holding the goal
  - If a team member discovers the goal to be achieved, unachievable, or no longer relevant, it will tell its teammates

Preliminary Insights

- Uszok: Ongoing analysis of agent teamwork research literature and implementations
- Feltovich and Bradshaw: Social science literature relating to teamwork underscores the importance of:
  - idiosyncratic values and construals of individuals
  - ongoing negotiation of agreements, not pre-fixed commitments
  - increasing feedback and situation awareness as autonomy and number of team members increases
  - real-time control and adjustability of autonomy
  - ability to flexibly recover from unforeseen events
- Sierhuis: Teamwork in practice is not so much about “joint goals” as it is about:
  - context
  - awareness
  - identity
  - history

Project Overview


Prior Work
Brahms
KAoS & NOMADS
PSA Testbeds
Project Plan
1.1 Perform Astronaut Work Practice Study
1.2 Develop Human-PSA Work Systems Design
1.3 Extend Teamwork Theory
2.1 Integrate Agent Frameworks
2.2 Initial Mockup Using Selected PSA Testbed
3.1 Do Human-Robotic Collaboration Experiments and Evaluate Results
3.2 Evaluate generalizability

KAoS Policy-Based Domain Management Services

- *Domain management capabilities* aim to:
  - facilitate the structuring of agents into organizational structures, administrative groups, and task-oriented teams
  - allow for complex structures and intensionally-defined domains
  - provide a common point of administration and policy enforcement
- *Policies* aim to:
  - assure coherent, safe, effective, and natural interaction among teams of human and artificial agents
  - reduce the need for special-purpose recovery and exception-handling procedures
  - assure efficient and robust agent behavior while keeping team maintenance overhead to a minimum

KAoS Policy Ontologies (KPO)

- **DAML+OIL representation:**
  - Basic ontologies for actors, actions, targets, places, policies (later, time)
  - Extensions for Java security, Nomads mobility and resource control, and KAoS domain management
  - Platform-specific and application-specific extensions
  - Distinguishes between *authorizations* (actions that are permitted or forbidden) and *obligations* (actions that are required or where a requirement is explicitly waived)
- **Provides basis for inference mechanisms:**
  - Policy analysis
  - Policy disclosure management
  - Reasoning about actions
  - Policy specification
- **Synergy with DAML-S**

Roles of Agent Frameworks

Brahms agents know how to perform activities, based
on how people do them in practice.

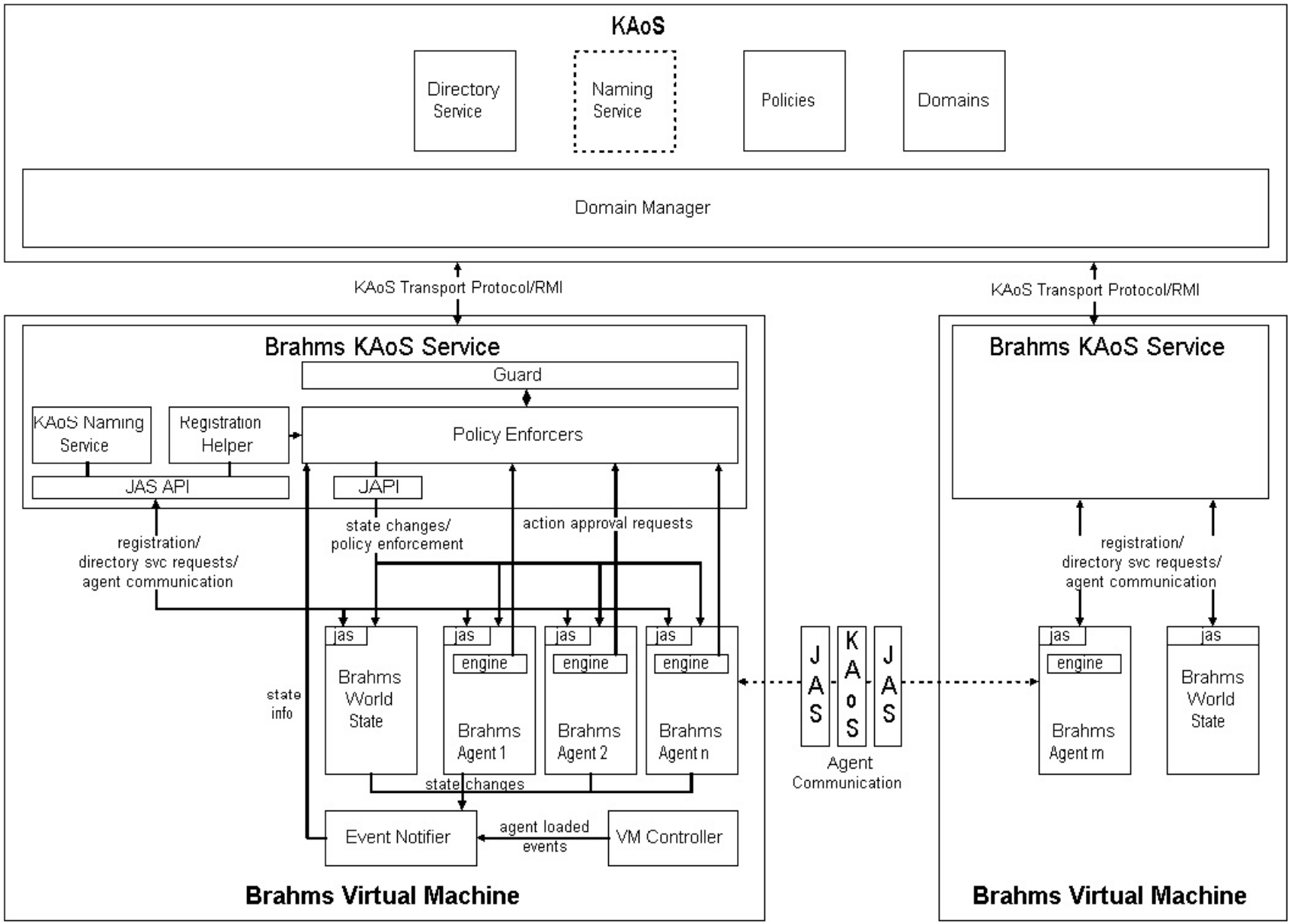
KAoS represents principles of safe and effective human-agent teamwork as policies.

Brahms provides needed contextual parameters to extend and tune the KAoS teamwork model to the situation.

KAoS assures that agent activities are performed consistent with policies, even when the agents themselves are buggy or policy unaware.

The strong mobility and safe execution features of

Integration Architecture



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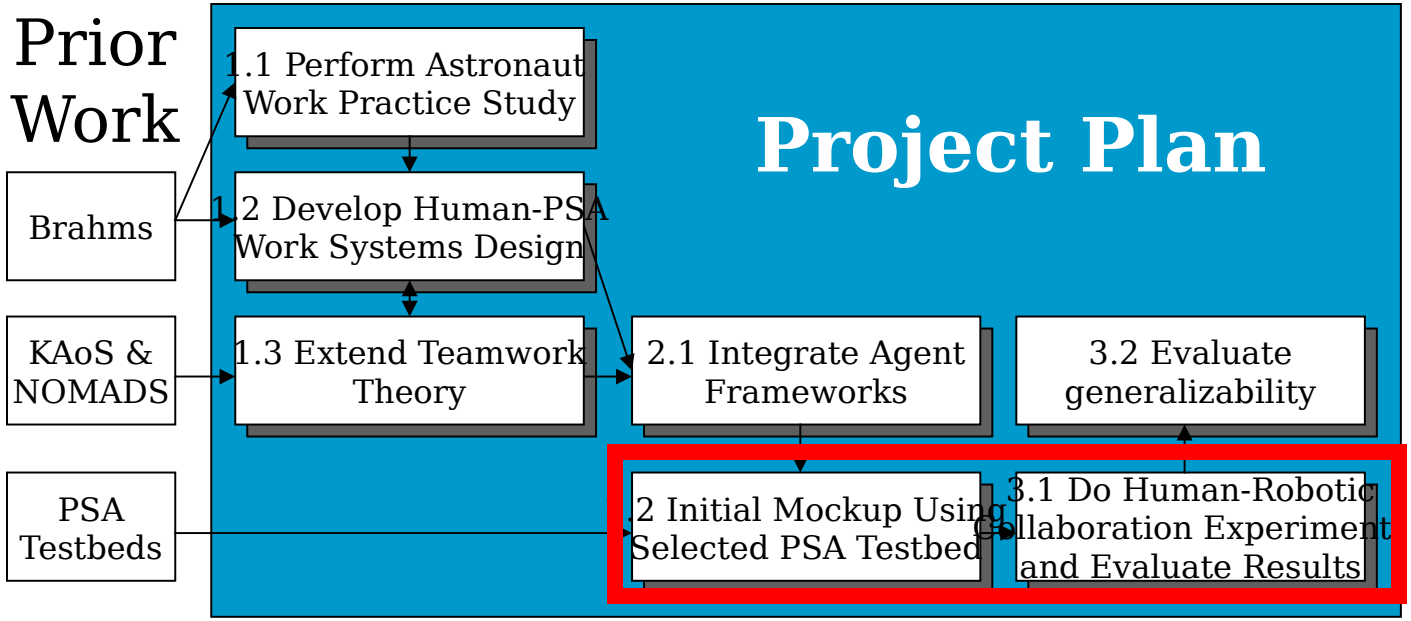
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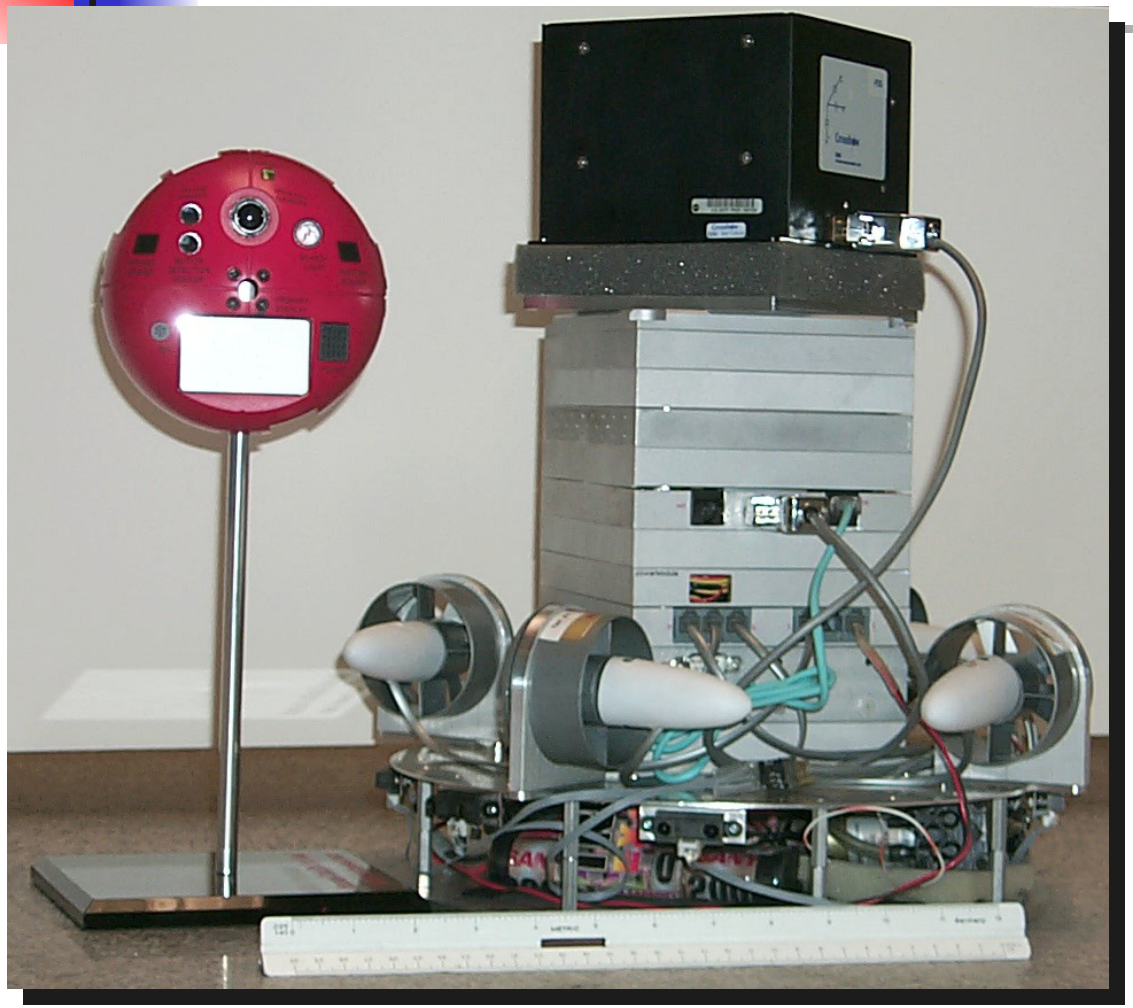
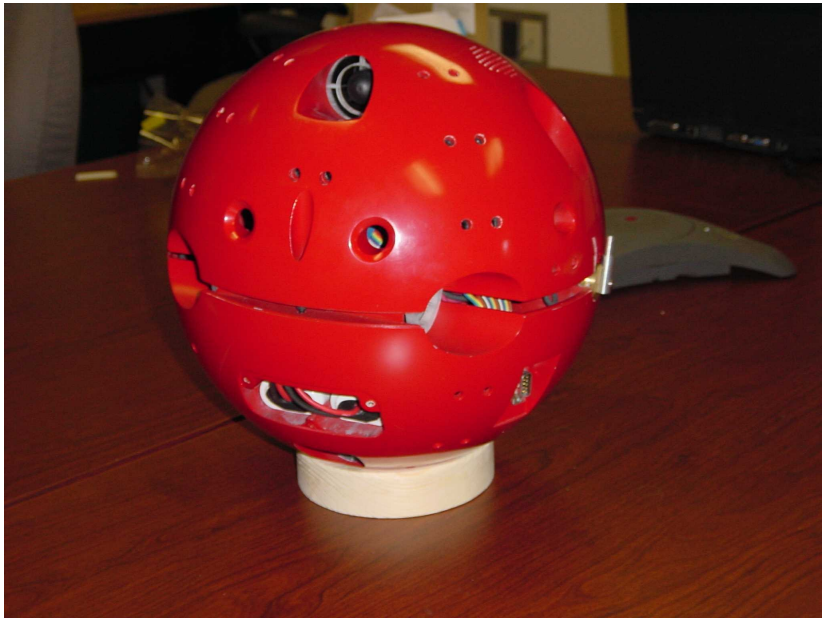
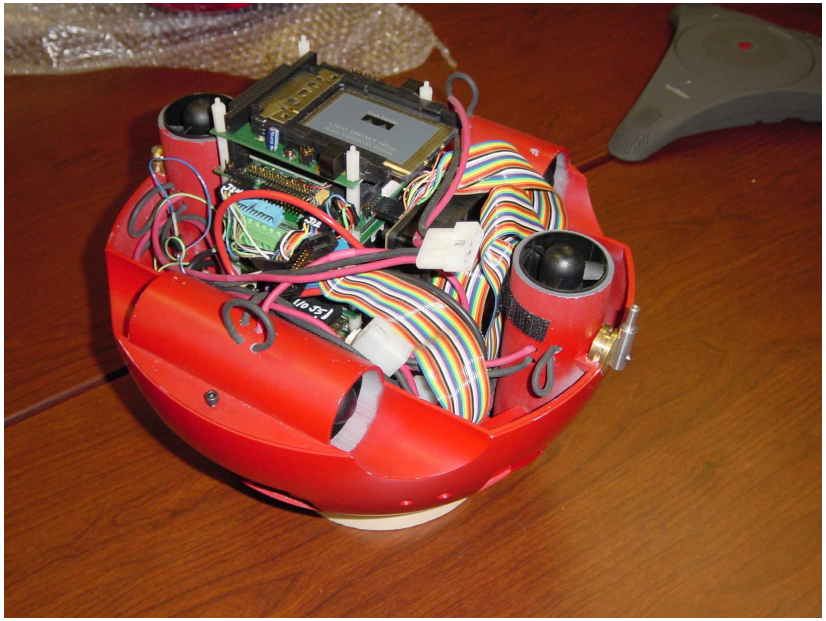
One G Testbed



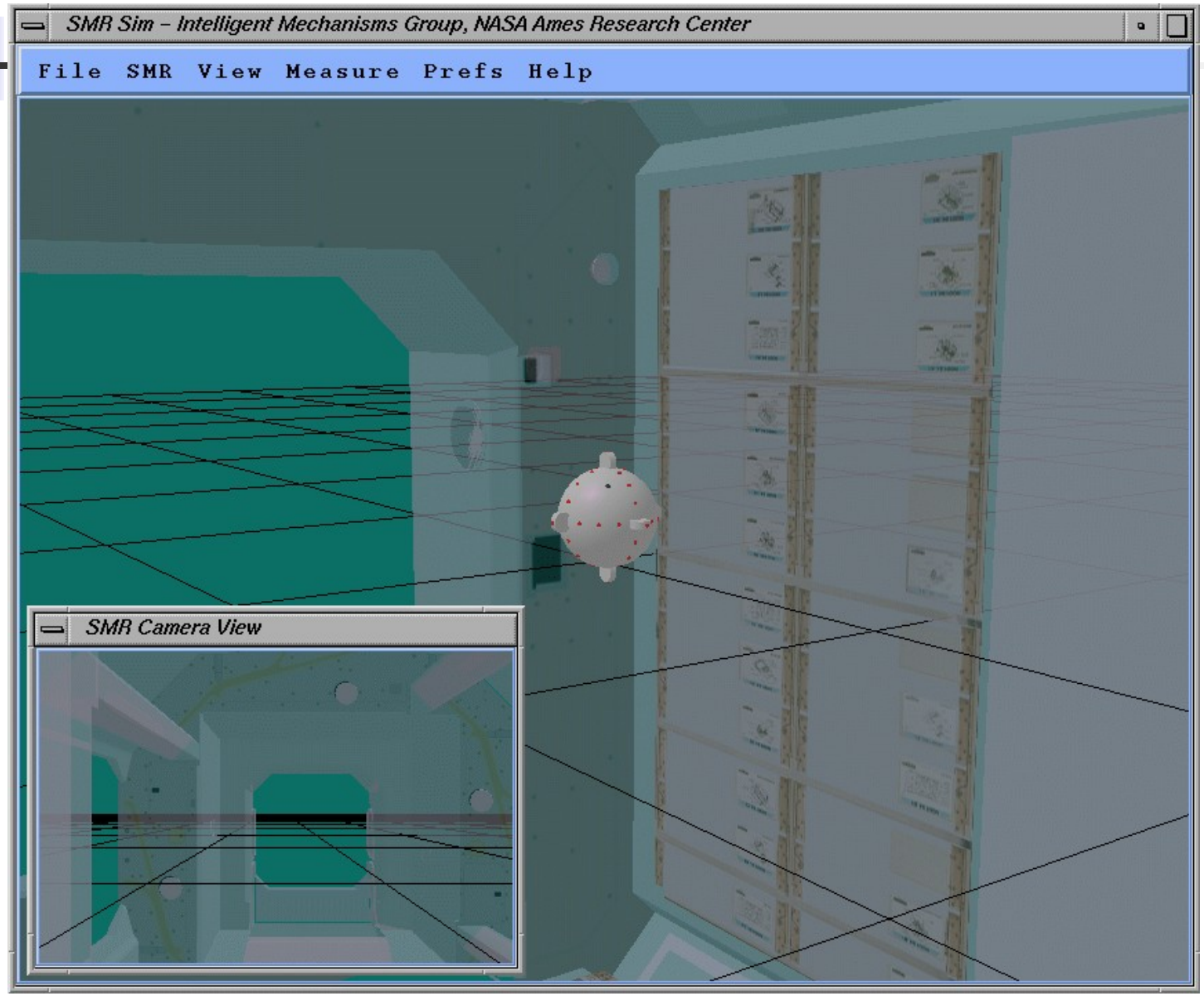
- COTS Hardware
- Linux OS
- Pump-driven air bearing
- Ducted Fan Propulsion
- FOG inertial meas. Unit
- Wireless Ethernet
- Onboard vision processing for visual tracking and depth measurements
- Off-board processing for
  - speech recognition
  - Sequence execution & Fault diagnosis

Current PSA “Basketball-Size” Hardware Prototype





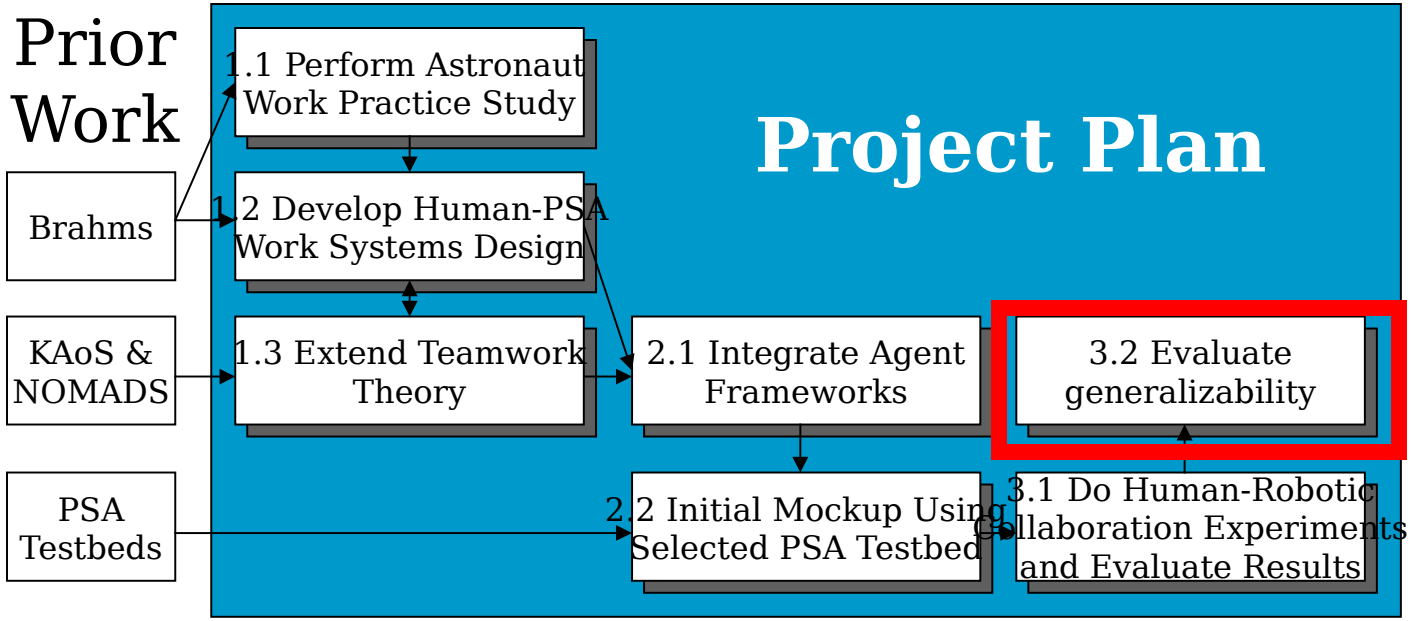
PSA Software Simulation Environment



Status of PSA Experimental Scenario

- Scenario will be simulated using the Brahms model
- Possible fire or leak inside station
  - Situation may precipitate a medical emergency (Jack Smith, Kathy Johnson, Medical Informatics at JSC and University of Houston)
- Initial link up of Brahms and KAoS completed March 1
- Initial Level 0 effort to represent for some minimal portion of emergency scenario and test policy-based mechanisms
- Level 1 effort to implement full scenario
- Collaboration experiments will take place in year 3

Project Overview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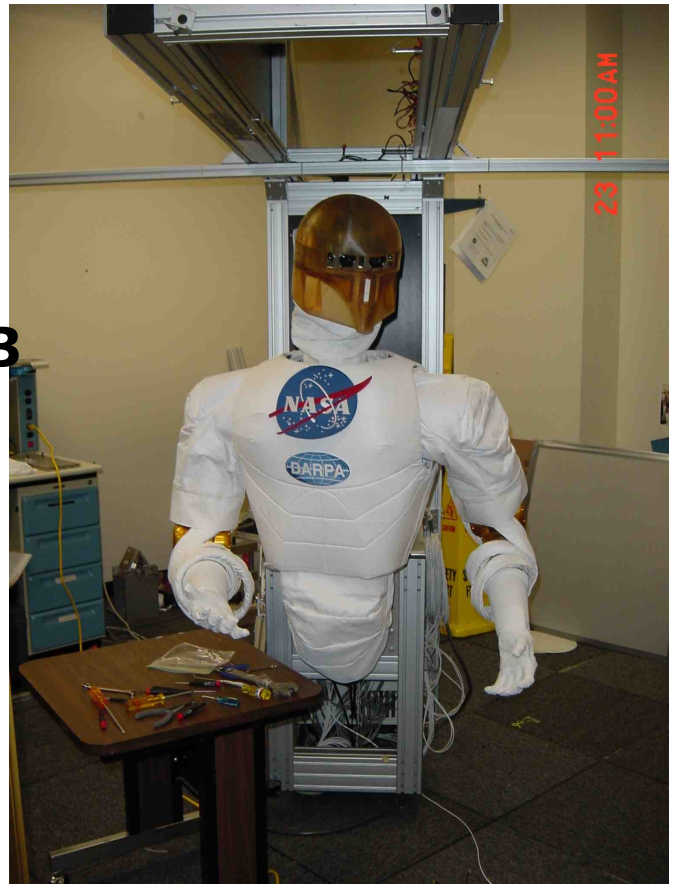
Other Robotic Testbeds

Possibility of EVA scenarios in connection with JSC Robonaut (Rob Ambrose) and Mini-AERCam (Steve Fredrickson) projects



Teamwork involving 3 humans and 3 robots:

- Robonaut, at site, controlled from within ISS
- Aercam, at site, controlled from within ISS
- SSRMS manipulator, at site, controlled from within ISS
- Human in suit, at site, standing on SSRMS manipulator
- Human in ISS, controlling Robonaut

Summary

- Interactive autonomous systems such as the PSA and Robonaut will require understanding of human-robotic collaboration *in practice.*
- Appropriate design approach and effective tools will be needed to make the development and deployment of such systems practical.
- Preliminary results are yielding useful insights about teamwork that will be represented as KAoS policies.
- Initial integration of executable KAoS, Brahms, and NOMADS system is completed.
- Initial experimental scenarios are being designed and implemented.
- Belief that results can generalize widely.

CoAX – Coalition Agents eXperiment

AIAI, BBN, CMU, U.Dartmouth, DSTO,
GITI, Lockheed Martin ATL, U.Maryland, U.Michigan,
Potomac Inst., QinetiQ, USC/ISI, UTexas, UWF/IHMC

Support from AFRL, ARL, Boeing, DREV, DSTL, ISX, MITRE,
MIT Sloan, NRL, NWDC, OBJS, Schafer, Stanford, TTCP

http://www.aiai.ed.ac.uk/project/coax/

Aim of Coalition TIE

- To address unique aspects of coalition operations through the development and evaluation of:
  - agent domain management services
  - agent task, process and event management services
  - other coalition-relevant agent services
- Aim will be met through delivery of:
  - phased technical demonstrations of increasing complexity
  - integration of diverse agent systems
  - development of generic Coalition-oriented grid services
- Requirements:
  - Use of a wide variety of different agent systems
  - Use of existing military (non-agent) applications

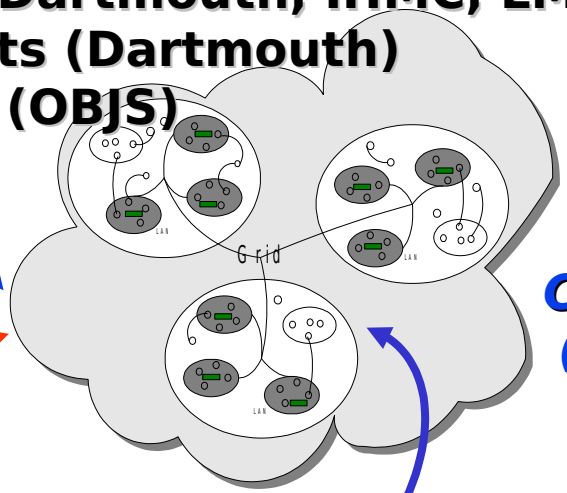
CoAX Components

Agents on the Grid

AODB Agent (LM-ATL)
Observer Agents (Dartmouth)
eGents E-mail Agents (OBJS)
Malicious Agents (IHMC)
Web Weather Agent (USC/ISI)
…

Agent Frameworks

KAoS Agents (IHMC)
NOMADS Mobile Agents (IHMC)
EMAA/CAST Agents (LM-ATL)
GMAS (Dartmouth, IHMC, LM-ATL)
D'Agents (Dartmouth)
eGents (OBJS)



DARPA CoABS Grid (GITI, ISX)

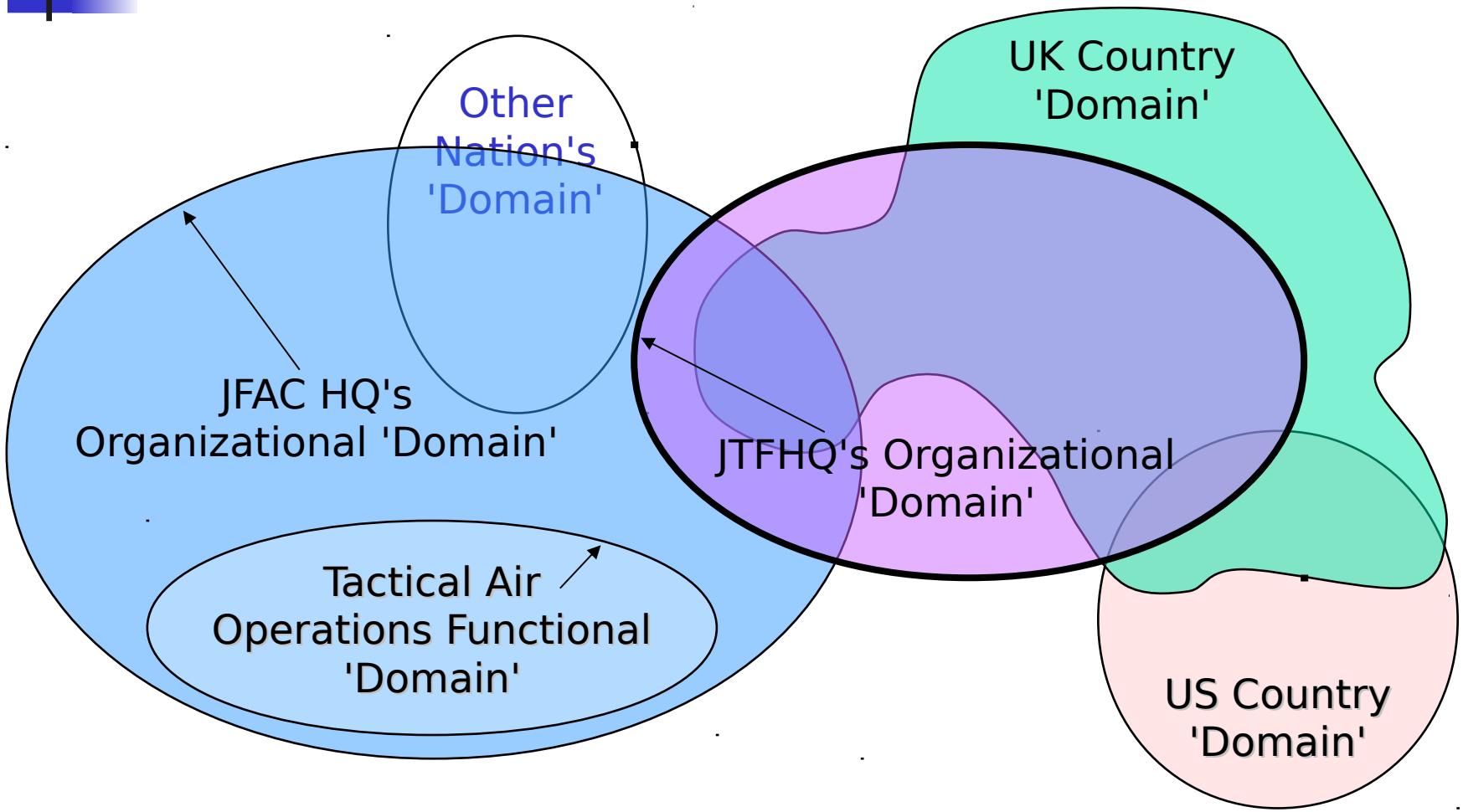
Military Systems

CAMPS (AFRL,GITI, BBN)
MBP (QinetiQ)
Situation Viewer (QinetiQ)
…

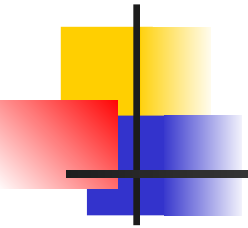
Agent Grid Services

Task, Process and Event Management (
Domain Management Services (IHMC)
Asynchronous Wireless Connectivity (O
Plan Deconfliction (Michigan)

Coalition Domain Types in CoAX



Agent Domain Management in CoAX



- Goes beyond typical distributed security concerns to include:
- Access management: Who can access what services?
- Resource management: Who can have which kind and how much of a given computing resource?
- Mobility management: What constraints should be placed on mobile code?
- Registration management: Who can join the domain under what circumstances?
- Communication management: What constraints govern interaction between conversing agents?
- Obligation management: Are agents meeting their commitments?

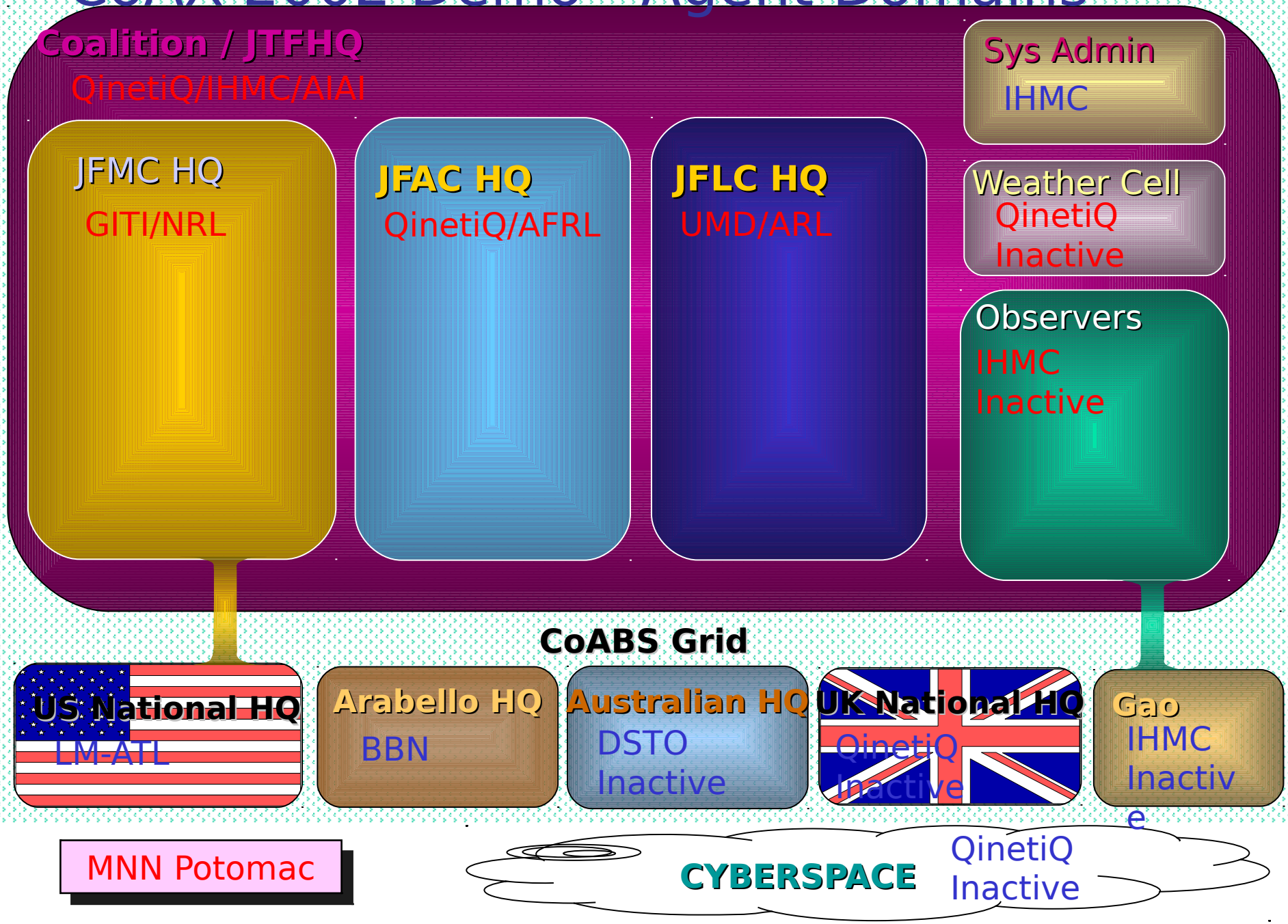
Demonstration Schedule

- 1-month demo at kick-off in February 2000 showing direct connection between DERA MBP and LM ATL AODB
- 6-month integration milestone in July 2000 showing initial integration of selected CoAX components for year 2000 demo
- CoAX Binni 2000 demo in Fall 2000:
  - Briefing the CoAX TIE and Binni scenario
  - Showing full integration of selected CoAX components in Binni
  - Telling a relevant “story” about agents for information gathering
- CoAX Binni 2001 demo in Fall 2001:
  - Fully integrating all CoAX components in a rich coalition scenario
  - Expanding scope to cover dynamic re-planning
- CoAX Binni 2002 demo in Fall 2002:
  - Showing dynamic aspects of coalition organization, domain management, tasking and event handling
  - Expanding scope to cover dynamic planning, coordination and execution.

CoAX Binni 2002 Demo Plan

- Dynamic “come as you are” coalition formation
  - Dynamic creation of ‘virtual coalition organization’
  - Agents and domains added to coalition structure ‘on-the-fly’
  - Dynamic coalition tasks and processes
- Tailored visualizations / interface agents
- Tools to improve human / software agent interaction
- High-level tools usable without specialized training
- Packaged generic Grid services:
  - Domain management and DAML-based policy analysis
  - Task, process, and event management
- Involvement of more countries and organizations
  - USA – BBN – Mixed initiative agents and dynamic information flow
  - Australia – DSTO – Logistics planning or information fusion
  - Canada – DREV - discussions begun

CoAX 2002 Demo - Agent Domains



Multidisciplinary Teamwork (Linda Pierce, ARL)

Program Description & Objective:

- **Objective Force concepts require multidisciplinary teamwork**
- **Multidisciplinary teams require:**
  - **Shared understanding of culturally-based cognitive differences in decision making and teamwork**
  - **Tools for rapid team development**
  - **Collaborative tools for synchronization & flexible execution**

Assessed Current TRL: **TRL 3**

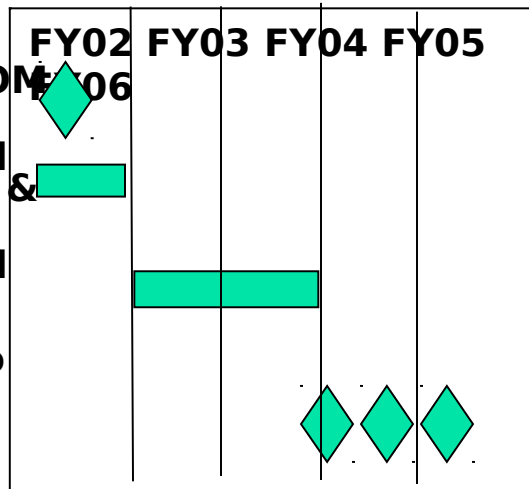
- Command requirements for FCS
- Decision and teamwork model and guidelines for leading and developing multidisciplinary FCS-based teams
- Methods and measures that mitigate the impact on of cultural differences in cognition on FCS
- Requirements for decision-centered collaborative tools for adaptable command to exploit FCS capabilities

Assessment Rationale:

- Researchers observed SFOR 8-9 team development in B-H (Oct 00, Jan 01, Mar 01, June 01, Sep 01)
- Observations revealed that:
  - Deployed teams are ill prepared to, and have limited understanding of, how to develop or support culturally diverse teams
  - Technology does not support distributed team operations or team adaptability in full spectrum operations

Schedule

- **MOAs with FORSCOM & USAREUR**
- **Interview deployed leaders and teams & define framework**
- **Interview deployed leaders using knowledge elicitation scenario for teamwork assessment**
- **Develop & implement training**



Proposed Cultural Differences in Cognition (Klein, Pongonis, & Klein, 2000)

Power Distance
- distribution of power
- interpersonal power and influence between superiors and subordinates
- influences how information is shared or received

Risk Assessment and Uncertainty Avoidance
- degree to which uncertainty or change is seen as stressful or risky
- extent to which actions are taken to avoid uncertainty

Activity Orientation
- doing, product oriented
- being, relationship or fun oriented

Dialectical Reasoning (reasoning about alternatives)
- maximize distinctions
- minimize distinctions and select the best aspects of alternatives

Counterfactual Thinking (what if)
- mental representation of alternatives (hypothetical)

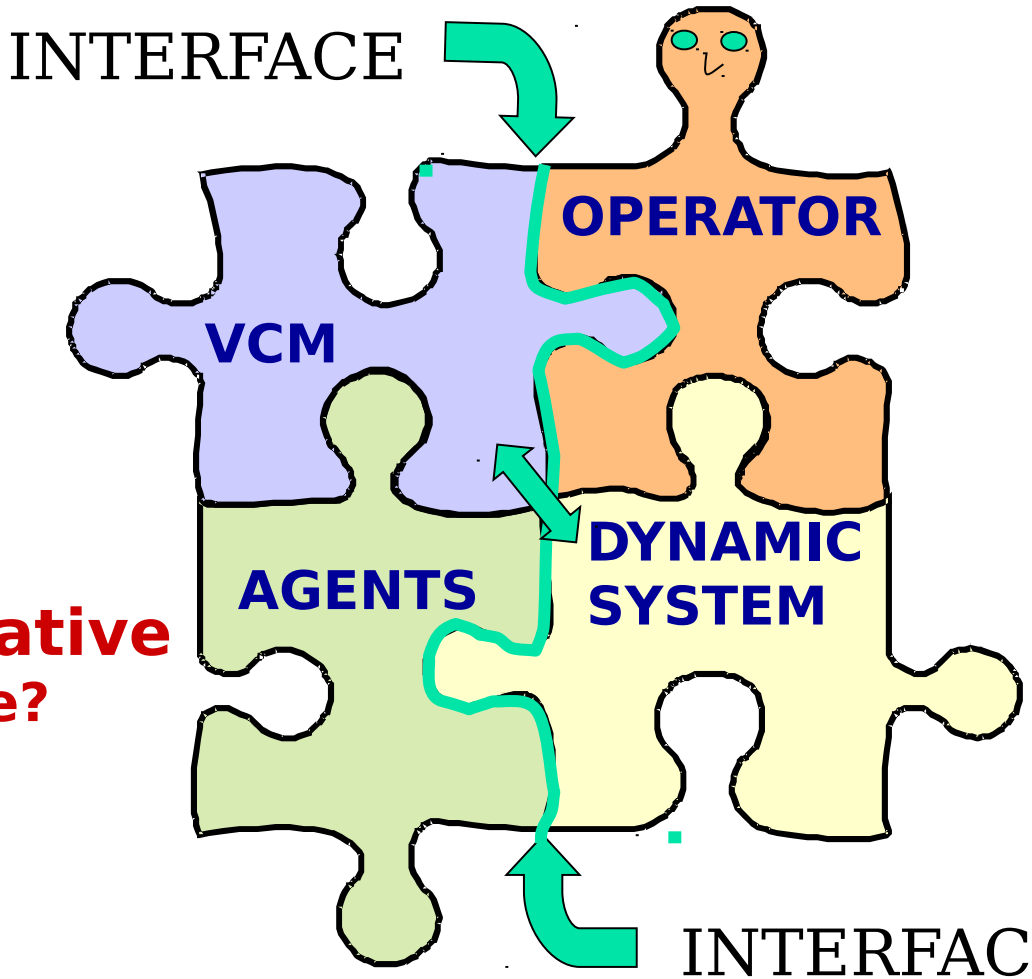
DARPA Augmented Cognition

QinetiQ

institute for Human & Machine Cognition

DARPA

Multi-sensory Adaptive Interfaces for Improved Decision Maki in Dynamic Environments



Reactive

Real-time!

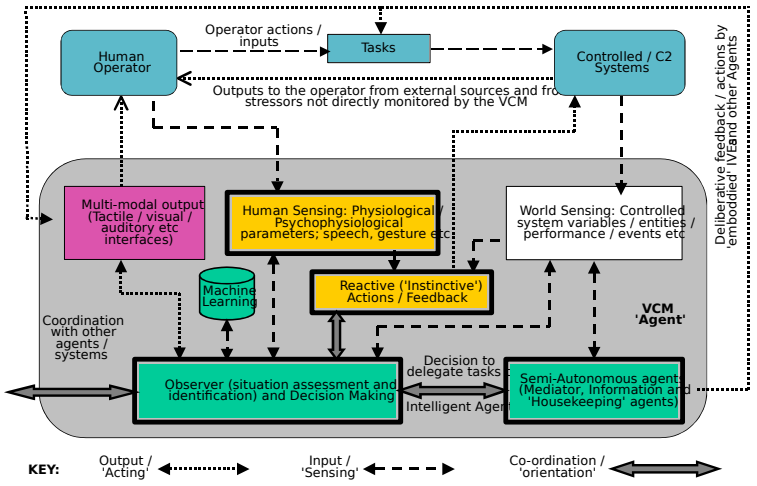
Deliberative

Real-time?

- **Balance system workload**
- **Human and machine monitor each other, human can override**

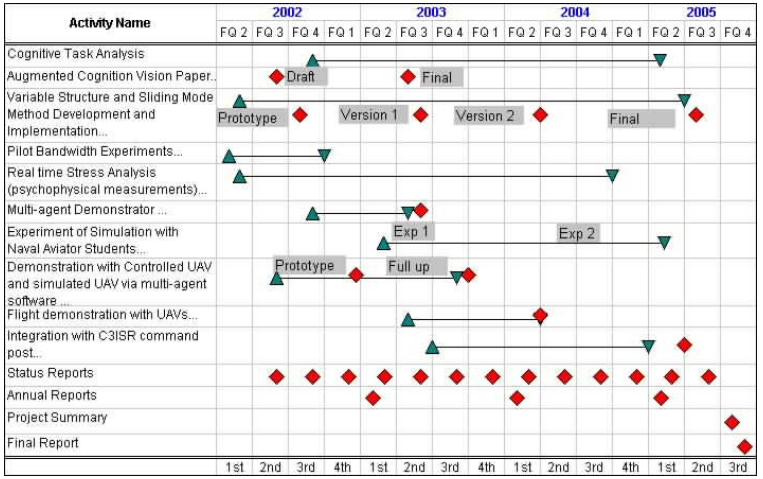
Multi-sensory Adaptive Interfaces for Improved Decision Making in Dynamic Environments

Virtual Crew Member


Human Operator
Operator actions / inputs
Tasks
Controlled / C2 Systems
Outputs to the operator from external sources and fr
stressors not directly monitored by the VCM
Deliberative feedback / actions by 'embodied' IVEand other Agents'
Multi-modal output (Tactile / visual / auditory etc interfaces)
Human Sensing: Physiological / Psychophysiological parameters; speech, gesture etc
World Sensing: Controlled system variables / entities / performance / events etc
Machine Learning
Reactive ('Instinctive') Actions / Feedback
VCM 'Agent'
Coordination with other agents / systems
Decision to delegate tasks
Observer (situation assessment and identification) and Decision Making
Intelligent Agent
Semi-Autonomous agent (Mediator, Information and 'Housekeeping' agents)
KEY:
Output / 'Acting'
Input / 'Sensing'
Co-ordination / 'orientation'

Goals for 2002

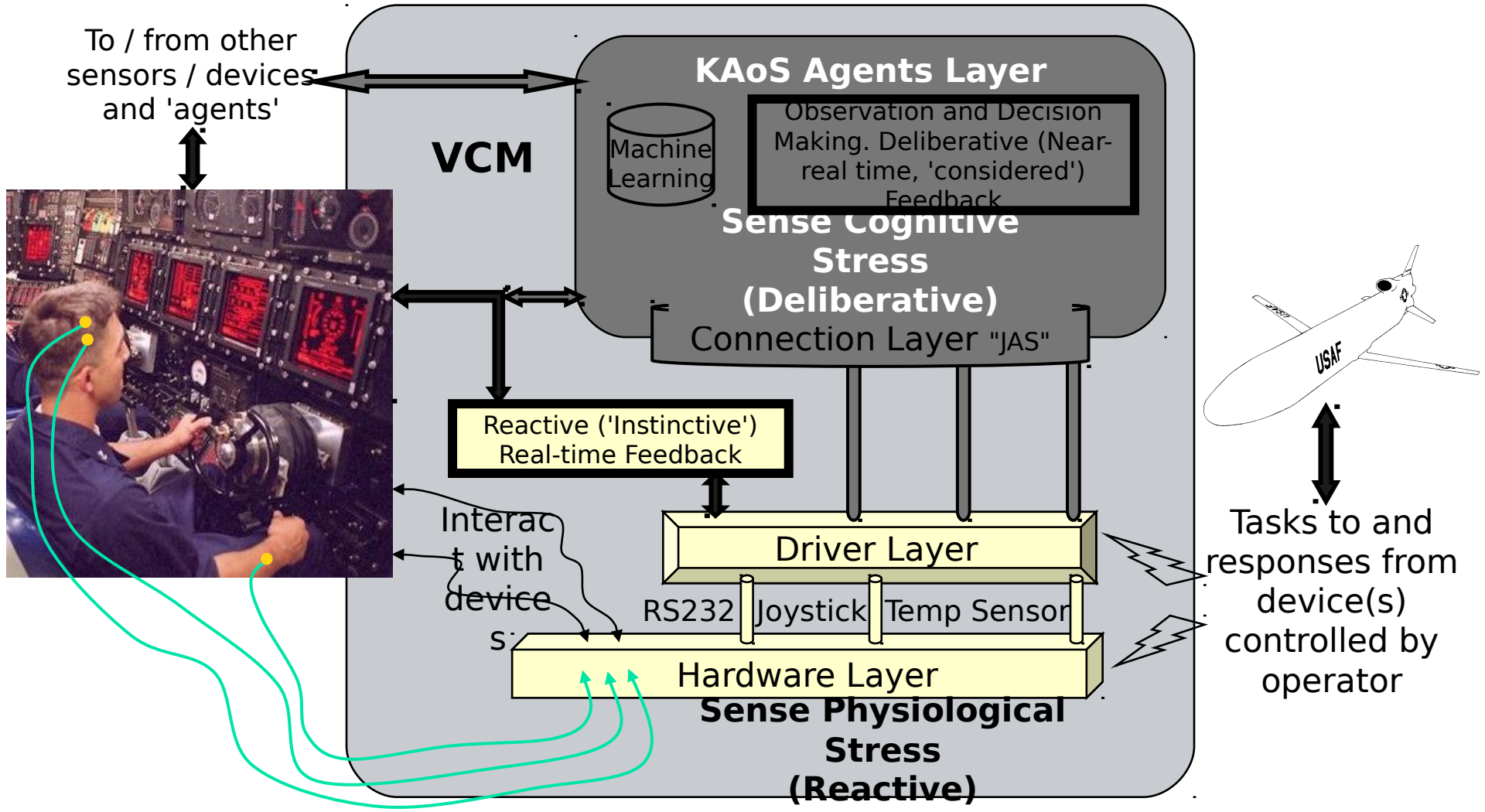
- Extend KAoS agent framework to provide an intelligent, flexible and scalable backbone for integration
- Evaluate physiologic measures of workload/stress and develop modular method of integration with above architecture.
- Determine sensory channel bandwidth limitations using current hardware.
- Demonstration of simple multi-sensory interface for control of multiple autonomous entities based on above.

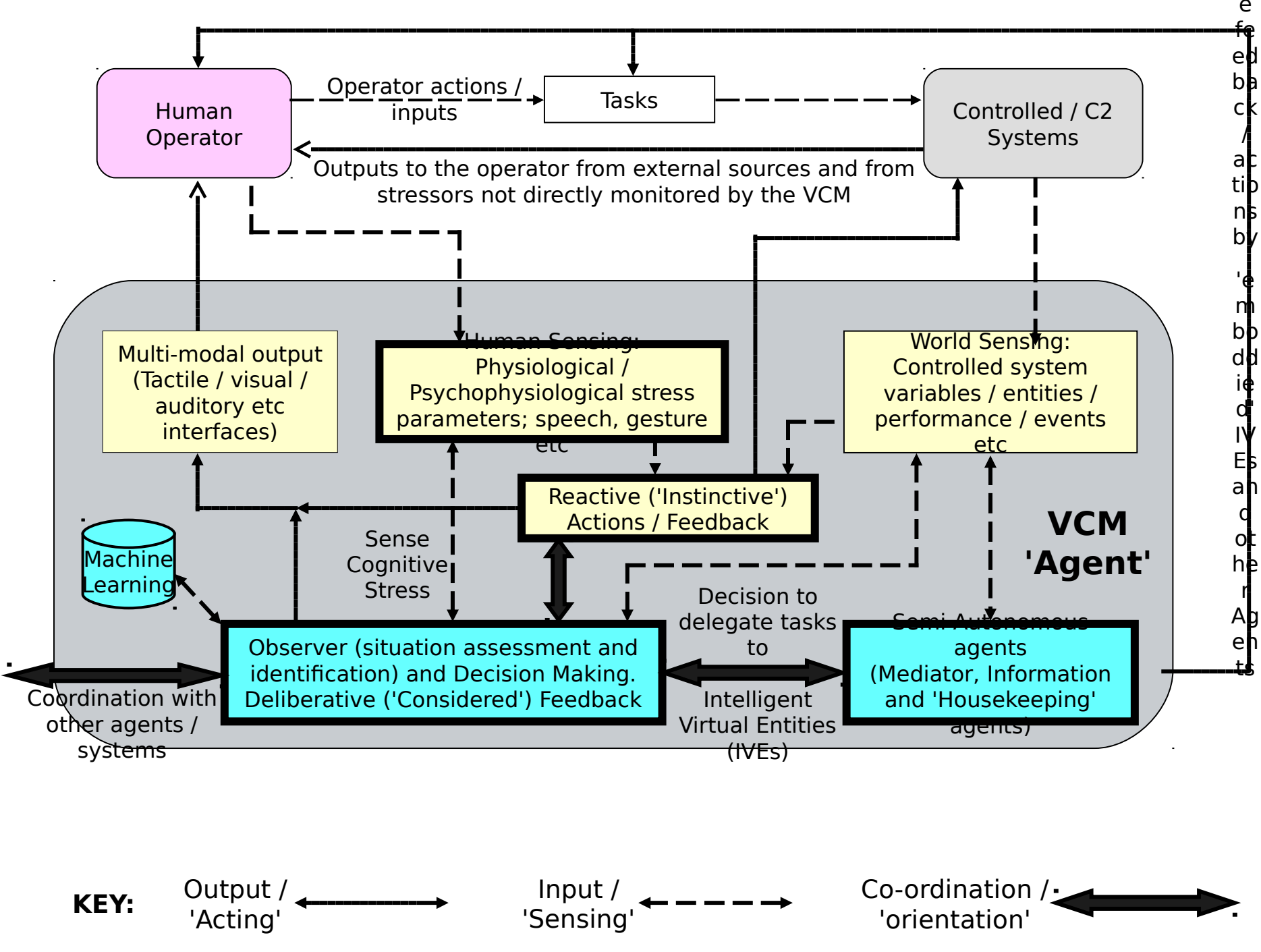

Activity Name
2002
2003
2004
2005
FQ 2 FQ 3 FQ 4 FQ 1 FQ 2 FQ 3 FQ 4 FQ 1 FQ 2 FQ 3 FQ 4 FQ 1 FQ 2 FQ 3 FQ 4
Cognitive Task Analysis
Augmented Cognition Vision Paper..
Draft
Final
Variable Structure and Sliding Mode Method Development and Implementation...
Prototype
Version 1
Version 2
Final
Pilot Bandwidth Experiments...
Real time Stress Analysis (psychophysical measurements)...
Multi-agent Demonstrator ...
Experiment of Simulation with Naval Aviator Students...
Exp 1
Exp 2
Demonstration with Controlled UAV and simulated UAV via multi-agent software ...
Prototype
Full up
Flight demonstration with UAVs...
Integration with C3ISR command post...
Status Reports
Annual Reports
Project Summary
Final Report
1st 2nd 3rd 4th 1st 2nd 3rd 4th 1st 2nd 3rd 4th 1st 2nd 3rd

Impact

- Reduction in stress associated with complex command and control tasks.
- Automated real-time adjustment of resources during changing stress, workload demand and during individual variations in cognitive ability to maximize performance.
- An intelligent, flexible, and scalable framework for interaction of heterogeneous agents interacting with

Basic Virtual Crew Member Architecture

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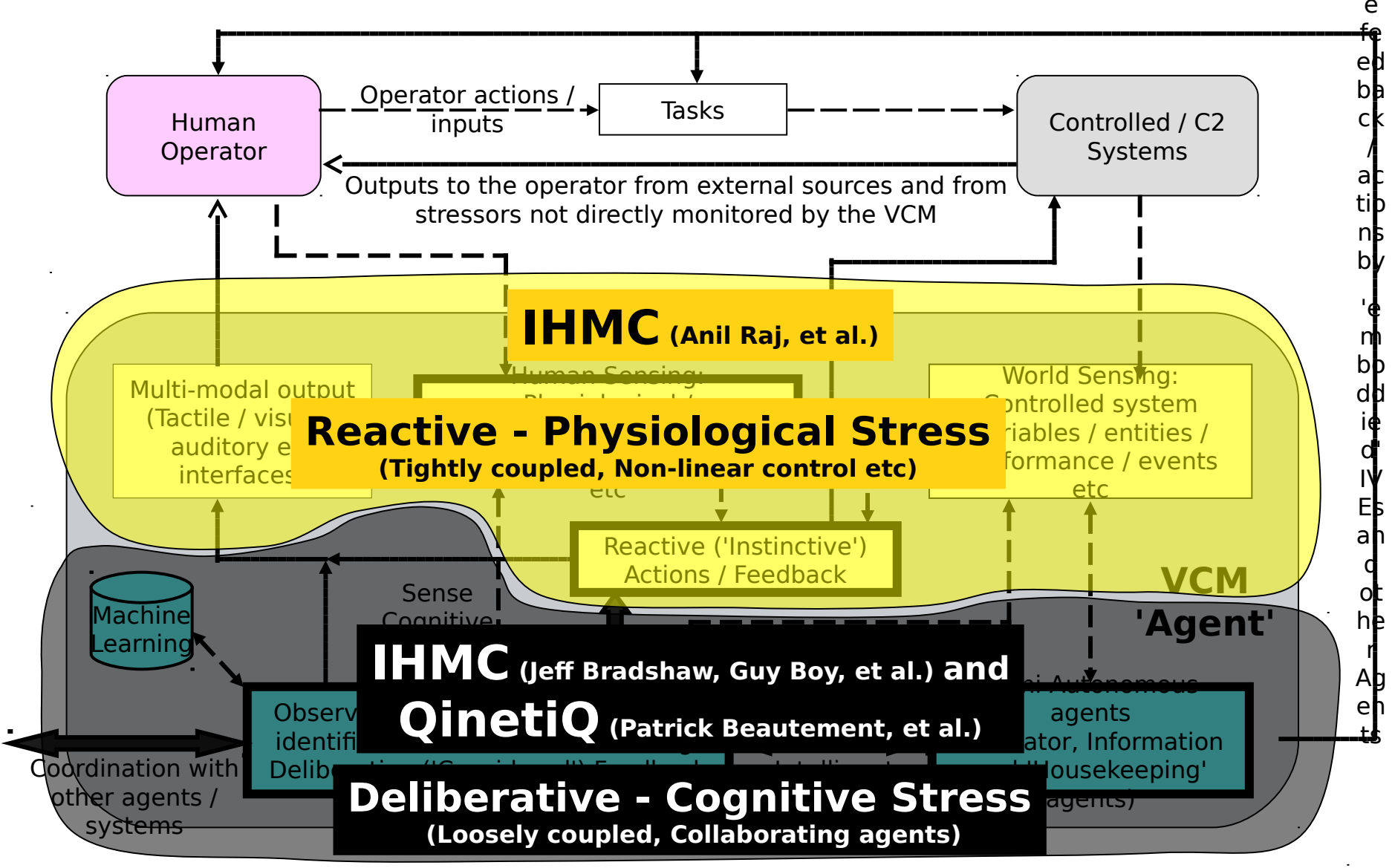
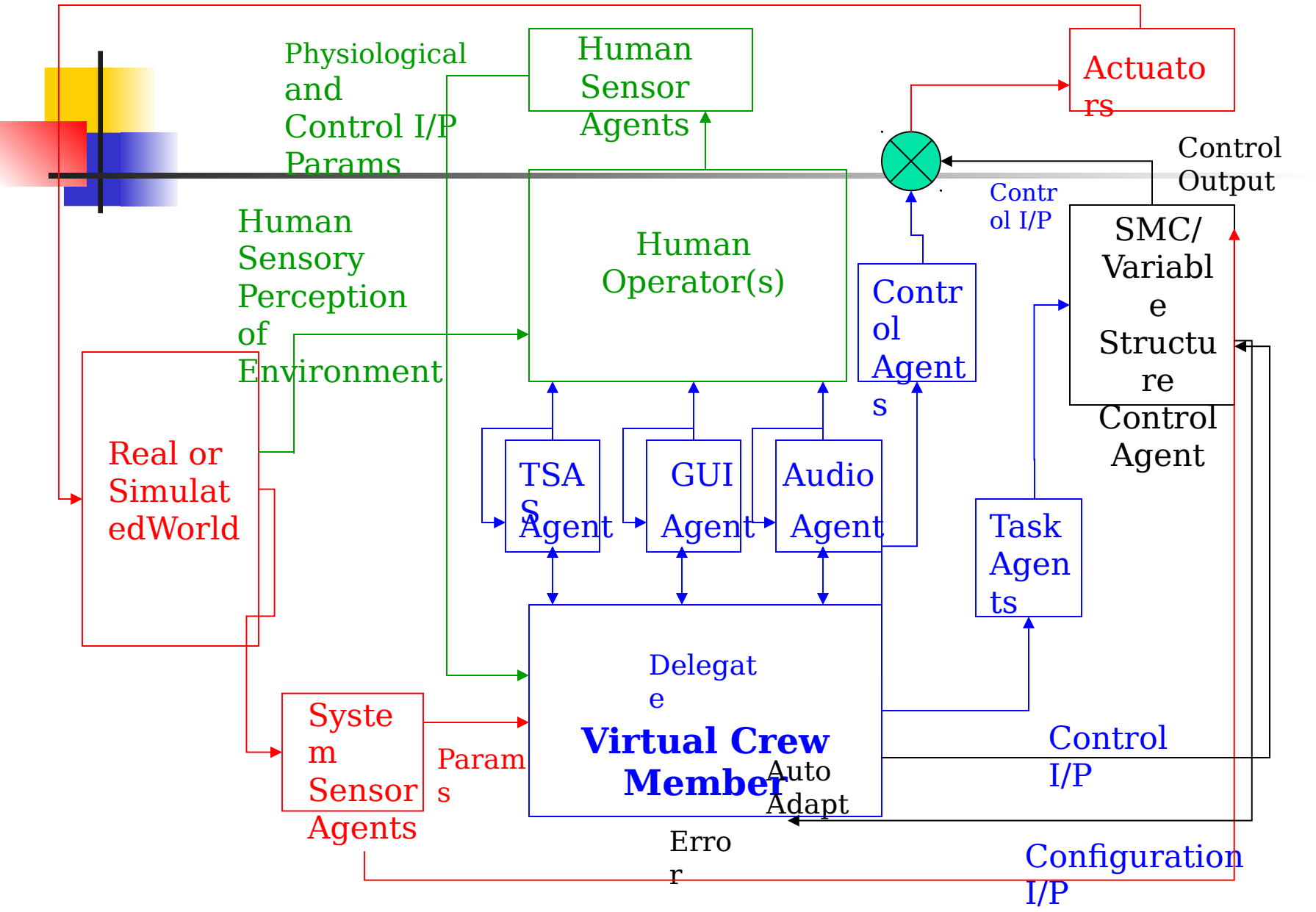
Decision to delegate tasks to
Observer (situation assessment and identification) and Decision Making. Deliberative ('Considered') Feedback
Semi Autonomous agents (Mediator, Information and 'Housekeeping' agents)
Coordination with other agents / systems
Intelligent Virtual Entities (IVEs)
Other Agents
KEY:
Output / 'Acting'
Input / 'Sensing'
Co-ordination / 'orientation'


Human Operator
Operator actions / inputs
Tasks
Controlled / C2 Systems
Outputs to the operator from external sources and from stressors not directly monitored by the VCM
IHMC (Anil Raj, et al.)
Reactive - Physiological Stress
(Tightly coupled, Non-linear control etc)
Multi-modal output
World Sensing:
Reactive ('Instinctive') Actions / Feedback
VCM
'Agent'
Machine Learning
IHMC (Jeff Bradshaw, Guy Boy, et al.) and QinetiQ (Patrick Beautement, et al.)
Deliberative - Cognitive Stress
(Loosely coupled, Collaborating agents)
Coordination with other agents / systems
'housekeeping'

Areas of Research Responsibility


Physiological and Control I/P Params
Human Sensor Agents
Actuators
Control Output
Control I/P
Human Sensory Perception of Environment
Human Operator(s)
Control Agents
SMC/ Variable Structure Control Agent
Real or SimulatedWorld
TSAS Agent
GUI Agent
Audio Agent
Task Agents
Delegate
Virtual Crew Member
System Sensor Agents
Params
Auto Adapt
Control I/P
Error
Configuration I/P
Params

"I/P"=INPUT

Agent-Based Integration of VCM Components

- Original TSAS architecture
  - Fly-by-wire scenario with direct connections between the pilot inputs and the motion model
- First-cut AugCog implementation
  - Single central peripheral server agent sending joystick data to sliding mode controller agent (stand-in for VCM)
  - SMC creates input for motion model
- Future AugCog implementation
  - Set of system sensor agents (e.g., joysticks)
  - Set of human sensor agents (e.g., EEG, pupil tracking, arousal meter, heart rate variability)
  - Set of human display agents (e.g., tactile, audio, GUI)
  - More sophisticated VCM
    - Nonlinear observer implementation for robustness in the face of erroneous or ambiguous data
    - Natural, effective dynamic delegation of cognitive functions among VCM and human
  - Control and task-specific agents

Human-Agent Teamwork: Lessons Learned and Future Research

- Need to inform models of human-agent teamwork with work practice study experience
- Need to assure that intelligent autonomous agents operate within the bounds of established teamwork and safety policies and are continually responsive to human control
- Need to assure that behavior of agents respects contexts established by complex organizational structures
- When agents are operated across multiorganizational/ multinational/multicultural settings, need to understand and take different perspectives, levels of trust, doctrines, and modes of operation into account
- Need to consider overall performance of joint human-agent system: human capabilities augmented by “cognitive prostheses”

For More Information

- KAoS: Toward an industrial-strength generic agent architecture, in J.M. Bradshaw (Ed.), Software Agents. 1997, AAAI Press/The MIT Press: Cambridge, MA. pp. 375-418.
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- Agent-Based Modeling of Collaboration and Work Practices Onboard the International Space Station. Proceedings of the Eleventh Conference on Computer Generated Forces and Behavior Representation, Orlando Florida, to appear.
- Terraforming Cyberspace, IEEE Computer, July 2001, 48-56
- Coalition Agents eXperiment: Multi-Agent Cooperation in an International Coalition Setting. IEEE Intelligent Systems, to appear.
- Agent Framework Support for Human-Robotic Teamwork in Practice, in Henry Hexmoor, Rino Falcone, and Cristiano Castelfranchi (Eds.), Agent Autonomy, Kluwer, to appear